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MASSEY

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PRACTICAL ELECTROTHERAPEUTICS AND DIATHERMY

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PRACTICAL ELECTROTHERAPEUTICS AND DIATHERMY

BY

G. BETTON MASSEY, M.D.

Fellow and Former President American Electrotherapeutic Association; Member Philadelphia Obstetrical Society; Former Surgeon to the American Oncologic Hospital; Former Gynecologist to Howard Hospital; Former Electrotherapeutist to the Philadelphia Orthopædic Hospital and Infirmary for Nervous Diseases; Former Assistant Physician to the Danville State Hospital for the Insane

Author of "Electricity in the Diseases of Women"; "Conservative Gynecology and Electrotherapeutics"; and "Ionic Surgery in the Treatment of Cancer"

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PREFACE

The present work is designed to furnish students, surgeons and general practitioners with the basis for a practical understanding of the application of electric power, as received from the street mains, in the treatment of their patients, the aim being orderly simplicity as well as comprehensiveness in the consideration of the subject.

The use of the physical forces in surgery and medicine, and particularly of those applications of electric power resulting in chemical and thermic changes in the body tissues, ionization and diathermy, has made such progress in recent years in the hands of an increasing number of general and orthopædic surgeons engaged in the reconstructive work of industrial medicine, that the physics, technic and clinical applications of this force need a systematic restatement for teaching purposes. The same need of a modern text book is also felt in the several recognized specialties, in which electric power is finding a wider use.

The older works on electrotherapeutics are no longer suitable for this practical instruction in a rapidly advancing science, even when attempts are made to bring them up to date. The best of them contain much archaic material descriptive of obsolete cells, batteries and methods that have long since been consigned to the scrap heap by active workers, thus confusing a subject that in itself is difficult enough to the busy surgeon or physician. Moreover, too many writers of books on the subject continue to copy the mathematical formulas of the early writers without realizing that medical men do not think in such terms after leaving college as do engineers, but need statements in the concrete for complete comprehension. As the algebraic formulas are not accompanied by a paraphrase in simple language, the student who is rusty in his mathematics loses a most important comprehension of the laws of this form of power transmission in the body, with lessened ability to use it correctly. These older books, nevertheless, are often treasure houses of valuable clinical experience.

It is hoped that the present work will contribute to the passing of electrotherapeutics as a specialty in practice, save as the

subject is taught by one well versed in it in postgraduate courses, for it is impossible for any one practitioner to develop expertness in the many special fields in which electric power is useful. It is to advance this result that chapters have been prepared for the general surgeon, the industrial surgeon, the gynecologist, urologist, dermatologist, rhinologist, ophthalmologist and neurologist, while help is offered in a new specialty, that of oncologist. A common introduction to the use of electric power in the living body in the fore part of the book is an essential portion of each clinical section.

The author disclaims expert qualification in most of the specialties treated of, and merely offers suggestions of the proper technical procedures to those capable of their expert application.

The attention of practitioners of the semi-surgical specialties is called to the minute directions given in each clinical chapter for the construction of simple electrodes for ionization and electrocoagulation surgery. These can be made by the physician himself, or by a locksmith, from the precise directions in the text. The application often consumes the metal of which the electrode is made or otherwise injures it, some instruments lasting only through a single major operation. Hence cheapness of replacement is an advantage.

But a more important reason why specialists employing electric power within narrow cavities should be able to construct electrodes personally, is that the method of insulation by sealing wax and the flame produces a far more delicate and accurate electrode than any that could be put on the market ready insulated. These electrodes with sealing wax fused on for insulation require re-insulation in this manner before each use, thus also ensuring sterilization. A really merchantable article for use within small cavities must have lasting hard rubber insulation, and is often made too clumsy by this insulation for the best work.

The author takes this opportunity to thank Dr. Bradford Massey for valuable assistance in the preparation of the work.

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PRACTICAL ELECTROTHERAPEUTICS AND DIATHERMY

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CHAPTER I

THE ELECTRIC NATURE OF MATTER

INTRODUCTORY—THE ELECTRON—THE ATOM—THE ION.

The surgical and medical uses of electricity include all those applications of electric power transformed into chemical action, forced osmosis and heat which may be employed for the correction of diseased conditions. Too much stress cannot be laid on the fact that in surgical affections particularly electricity acts exactly as in its industrial uses, that is: merely as a carrier of power to be transformed into some other form of force within the structure into which it passes, and that it is this resultant force which is actually employed as a surgical instrumentality. One does not say, for instance, that an amputation was done with an arm that wielded a knife but with the knife itself; similarly, one should not think alone of the agency by which a force is carried into the body, but of the thing into which it is changed while passing through. When this distinction is fully grasped by the surgeon there will be fuller recognition of the possibilities of the transformed products of electric power in his work.

The forces that may be *released by electric power within the living human tissues* are chemical; thermic (diathermy); osmotic; magnetic (for removal of iron and steel particles only); and the physiologic responses of parenchymal cells, neurons, muscle fibers, etc., the latter including mechanical effects.

The forces that are *applied to the body by electric power* are thermic (the cautery knife, thermotherapy, etc.); vibration; light; aspiration; cupping; air compression; motor-driven tools, etc. These latter are also important services of electric power in

surgery, but, save for the thermic product, are outside the scope of the present work and adequately discussed elsewhere.

Of the surgical effects of electric power released directly within the tissues, the most important in the field covered by this work are chemical and thermic effects in various degrees, ranging from minutely localized accentuation of the normal chemical interchanges of a part for the quickening of the absorptive processes, or the production of similar effects by hyperemia, to the destruction of a minute or massive neoplasm in a few minutes under local or general anesthesia. These varying effects differ in magnitude only, involving the use of more or less power, or its greater or less concentration within the tissue in which it is released.

The Electron.—Since the discovery of the X-rays and radium it has been possible for physicists to determine with accuracy the nature of the atom; to ascertain positively that it is not the smallest part of matter; and to measure, weigh and count the electrons of which it is composed. We owe these results chiefly to J. J. Thomson, Rutherford, and other English physicists, whose conclusions, be it noted, are not theoretic or hypothetic, but facts based on actual physical measurements.

These facts are an excellent confirmation, one hundred and fifty years later, of the theory of Benjamin Franklin that there is but one kind of electricity, the opposite polarities and other dissimilar manifestations of its action being indicative of either an excess or deficiency of charge. A current of electricity is an actual flow of electrons in Nature's effort to establish equilibrium between an overcharged body and an undercharged body.

We now know that an electric current is, in a solid conductor, a flow of electrons carrying a cathodic charge. The flow of current in a liquid electrolyte is also only by cathodic electrons and in one direction, but, as will be shown below, there is a counter current of whole atoms with an electric charge, or ions, in both directions in a liquid electrolyte. In gases sufficiently rarefied to remove nearly all atmospheric pressure the remaining atoms of gas yield up their electrons to a current and appear as a cathodic stream, as in the X-ray tube.

All matter is composed of charged points or corpuscles of cathodic or negative electricity, called electrons, the atoms of the various elements being each composed of a definite number of electrons in accordance with their combining weights.

Hydrogen, the lightest atom, is composed of 770 electrons; the mercury atom of 150,000 electrons, and radium of even more. The relation of the electron to the atom is similar to that of the planets in our solar system to the solar system itself, the electrons being analogous to the planets and the atom to the solar system. Immense spaces exist within the atom for the ever moving electrons, even in the atoms with the greatest number of electrons. Sir Oliver Lodge calculated that if an electron be depicted as about the size of one of the full stops on this page, the space available for the few hundred or thousand of such constituent dots to disport themselves (or shall we not say, perform tactical evolutions?), inside an atom on the same scale is comparable to a hundred foot cube; in other words, an atom on the same scale would be represented by a room 160 feet long, 80 feet broad and 40 feet high—an immense space for 770 dots to perform evolutions in if the atom be hydrogen, or even 150,000 dots if it be mercury. Yet these dots are all that there is in the atom, *plus their accompanying force.* They "occupy" its volume in the sense of keeping other things out, as soldiers hold a country; they give it its inertia; they enable the atom to cling to other atoms which come within short range with the force we call cohesion; and by excess or deficiency of one or more electrons the atoms exhibit chemical properties and attach themselves with vigor to other atoms presenting a reciprocal defect or excess of electrons.

No anodic electrons have ever been found.

In solids, electrons may be found momentarily free, unattached to atoms, when conducting a current of electric power.

In fluids, electrons are found outside atoms to a greater extent than in solids, though they are not numerous if the fluid be composed of pure atoms, such as freshly distilled water. If the water contains a solid in solution that is capable of electrolysis an abundance of free electrons are present. The sea, for instance, is an immense storehouse of free electrons.

In gases, such as the air, free electrons are frequently present in abundance outside the atoms of oxygen, nitrogen and other constituents, particularly during and after a thunder storm. The souring of milk at these times is doubtless due to free electrons causing ionic change as they seek "cover" in atoms. They have been found in air near waterfalls.

If the atoms of the gas be removed from atmospheric pressure, as in a vacuum, an abundance of electrons emerge from the rem-

nant of atoms left in the vacuum, as foreshadowed by Crookes in the 70's; and if an electric current be caused to traverse the vacuum, as in an X-ray tube, a stream of electrons will be projected from the cathode at right angles to the surface of the latter, the X-rays themselves being developed by collision of the electrons with the glass walls of the tube. It is, in fact, from a study of the cathode stream that produces the Lenard, Hertz and Roentgen rays that the foregoing facts concerning electrons have been discovered. The cathode stream within the X-ray tube is composed of free electrons only. In eddies back of the cathode in tubes with a low vacuum counter streams of atoms may be found, now converted into anodic ions by the abstraction of some of their constituent electrons.

The Atom.—In spite of what has been said above, the atom is a formidable fact to our senses as *the smallest portion of an element in its form as an element,* irrespective of its divisibility into electrons. It is true, certain atoms, such as radium, are breaking down into electrons, ions or other elements, but so far the dreams of the alchemists of their transmutation are unrealized. For us they are the things that compose the definite contacts of our sense organs.

Take, for instance, the space of the large room given above for the small number of electrons of dot size circulating within it. It would seem that such a space would be hollow and void with so few defenders. Yet the power of the electrons, or defending soldiers, within the atom is the strongest in nature. If it could be released and utilized we would need no other power. It is this force, varying with each atom, that creates the strongest acids and the most biting alkalies—the hardest and the softest materials; living things and death.

The Ion.—An atom in its state of electronic equilibrium, with its full complement of electrons, possesses its special qualities as an atom. Phosphorus, for instance, if released from combination at once seizes an atom of oxygen and enters into combination again. If, however, it loses a certain number of its electrons, thus attaining a cathodic charge, it becomes an *ion,* in which condition it loses some of its atomic qualities temporarily and, if free to move in solution in water, it seeks and reaches the anode of a current traversing the solution, where it gives up its charge and regains all the qualities of an atom. Ions with a deficiency of electrons are known as *anions;* those with an excess of electrons are *cations.* Ions and ionization will be further considered in the chapter on the direct current.

CHAPTER II

CURRENTS OF ELECTRIC POWER

Static and Kinetic Power—Pressure or Voltage—Resistance—Volume or Amperage—Resistance Encountered by the Surgeon or Physician—Resistance of Metallic Conductors—Resistance of the Body Tissues—Mode of Conduction—Conducting Wires and Electrodes—Three General Modes in which a Stream of Electrons Is Applied in Medicine and Surgery.

Electric power as used by the surgeon or physician is in one of two conditions: static or kinetic. The static condition, in which power is manifested by static pressure alone, is well illustrated by static pressure in hydraulics. This latter is manifested by the varying weight or pressure of columns of water of differing heights confined in upright pipes. The pressure at the bottom of a standpipe 100 feet high is double the pressure at the bottom of one but 50 feet high. It increases directly with added height of the pipe, and if the column of water is high enough the pressure at the bottom may be made so great as to burst iron or steel walls.

The static pressure of electricity is but slightly used as such in medicine, for even in the electric modality known as static electricity it becomes a current always when actually used, save possibly in the variation known as autoconduction or static charge.

Kinetic or flowing electricity is the source of our usual electric power, the heaped-up electrons seeking a lower level when permitted to do so by a conductor, and performing work while flowing from the higher level to the lower level. Such currents of electric power have *pressure,* encounter *resistance,* and present *volume* of flow.

Pressure or Voltage.—Figures 1 and 2 illustrate diagrammatically the creation of pressure in a water current by the elevation of its reservoir, and the creation of electric pressure by the elevation of potential at one of the poles of an electric cell or

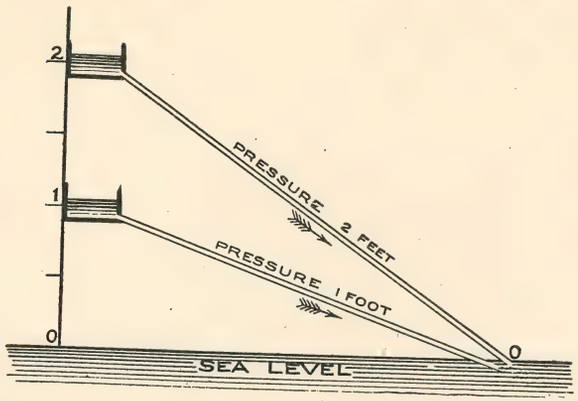


FIG. 1.—Diagrammatic Representation of the Cause of Flow in Hydraulic Currents. The pressure, measured by a vertical scale of feet, is due to the elevation of the source, or reservoir. The amount of water delivered will depend on the caliber of the pipe as well as on the height of the reservoir.

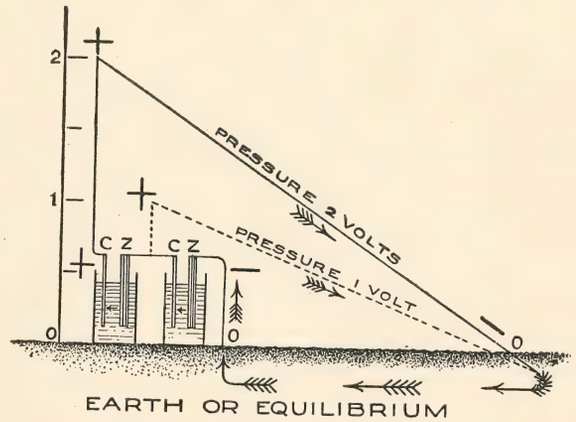


FIG. 2.—Diagrammatic Representation of the Cause of Flow in Electric Currents. The pressure, measured by a scale of volts, is due to the elevation of electric pressure in the positive end of a conductor of power from the particular generator in use, here a battery of two cells. The amount of current delivered will depend on the size and conductivity of the wire or other conductors in the circuit as well as on the height of this pressure.

battery of cells, while Fig. 3 shows that a dynamo pumps electric pressure into a circuit of wires or other conductors in a manner quite analogous to the pressure created by an hydraulic pump.

The unit of electric pressure is the volt. It was adopted originally from the pressure created in a copper-zinc cell.

Resistance.—A water current driven through a pipe and supplying a water motor with power presents two kinds of resistances: that due to the weight of the water pushed along and its friction against the sides of the pipe, and that due to the resistance of the water motor and its load. The first portion of this

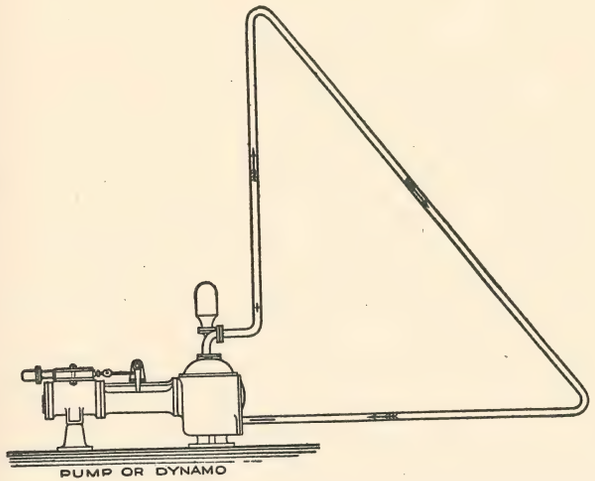


FIG. 3.—Diagram Showing Analogy of Laws Governing Pressure in Pump and Dynamo Circuits.

resistance will be lessened by increasing the size and shortening the length of the pipe.

An electric current similarly meets resistance in the conductors through which it is transmitted, the wires and the tissues. The larger and shorter the wire the less the resistance, the resistance being increased by increased length and lessened cross section.

The unit of resistance is the ohm, equal to the resistance of a column of mercury 1 meter high and 1 millimeter thick. A piece of copper wire 100 feet long and of the size used in electric bell wiring, No. 20, Brown & Sharpe gauge, will also give about one ohm resistance. The resistance of the human body from dry cuticle to dry cuticle may be as great as 3000 ohms.

Volume or Amperage.—As in the water currents, the volume of flow is determined by the height of the pressure, controlled by the size and length of the pipe, so in electric currents the volume of flow is a resultant of height of pressure and amount of resistance. The unit of volume is the ampere. In surgery and medicine this unit is too large, so the milliampere, or thousandth of an ampere, is the unit employed.

An ampere is the volume of a current from a pressure of one volt passing through a conductor with the resistance of one ohm.

The cut, Fig. 4, shows diagrammatically the relation of these units of electric currents to each other and their analogy to similar units of forces existing in water currents and resulting

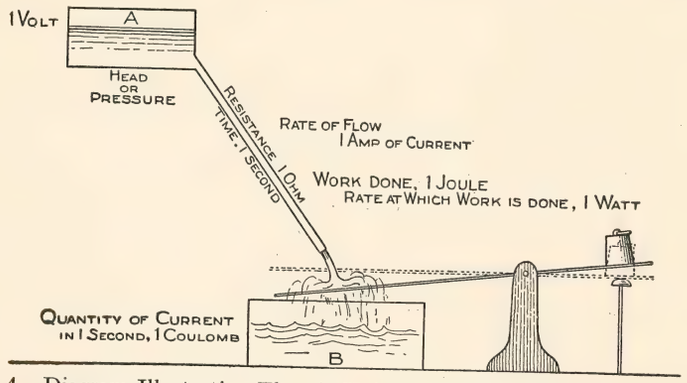


Fig. 4.—Diagram Illustrating Electric Units by the Water Analogy. (From Hedley.)

in hydraulic power. It shows the place of the coulomb and the joule in the series, units that are not needed in surgery and medicine, as the milliamperage of the current and its time of duration, or its wattage, is more significant in the conditions encountered.

The important meter to have on a direct current apparatus is therefore the milliamperemeter in the patient's circuit, its readings, taken in connection with an interval timer clock, giving us full data when the size of the electrodes is also recorded.

Ohm's Law.—The facts illustrated concretely and by analogy in the preceding paragraphs are all statements of the essential facts of Ohm's law, and are an attempt to make them easily comprehensible to medical men, who seldom think in formulæ after their emergence from the schools, as do engineers. They are the

basic facts of electrokinetic power, and unless they are properly comprehended the user of electric power remains lame in his efforts. The law is stated as follows:

The volume of a Current is equal to its Voltage divided by the total Resistance of the circuit, or

$$\text{C (current volume)} = \frac{\text{V (voltage)}}{\text{R (resistance)}}.$$

Arrangement of Cells for Low Voltage-High Amperage, and Higher Voltage-Low Amperage Outputs.—To the mathematical mind but little effort is required to comprehend the full meaning of this "Law of Ohm" formula of the relations of pressure, resistance and volume. To those rusty in figures and the rules of proportion I commend the appended graphic delineation of this law (Figs. 7, 8 and 9), as applied to currents from cell batteries, either primary or secondary.

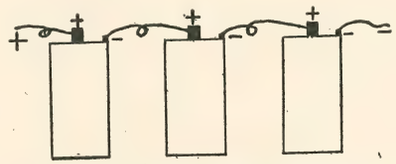


Fig. 5.—A Battery of Three Cells Connected in Series.

For convenience it is assumed that the cell taken for illustration has a pressure of 1 volt and a resistance of 1 ohm. As some of our readers may be compelled to use primary cell batteries in the absence of a power supply from street mains, it should be said that the true voltage of the only cells that any one should trouble to use, the standard dry cell of commerce, is about 1½ volts, and its internal resistance, when fresh, the mere fraction of an ohm. The arrangement of such cells would not differ greatly in power output nevertheless from that shown in the illustration, except in the output or volume obtained on short circuits and with the lower resistances shown in the diagrams. With the ordinary dry cell the output on short circuit and with the lower resistances in series would be about thirty times greater.

Figure 5 shows the method of coupling three or more cells in "series." With the negative binding post of the first cell connected with the positive binding post of the second, and the negative of the second with the positive of the third, we have the

positive binding post of the first cell as the positive pole or anode of this series battery and the negative binding post of the last cell as its cathode.

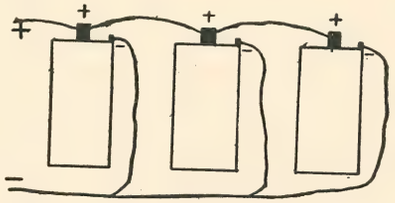


FIG. 6.—Three Cells Connected in Parallel Circuit, or for Surface.

In Fig. 6 the same three cells are shown connected up for "surface" or in parallel, all the positive binding posts going to

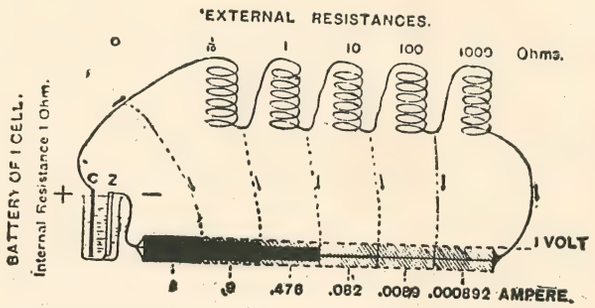


FIG. 7.—Graphic Delineation of the Pressure and Volumes of Currents from a Single Galvanic Cell when Various Resistances are Inserted into the External Circuit. The cell shown at the left of the cut has an electromotive pressure of 1 volt and an internal resistance of 1 ohm. The divisions of the drawing to the right of the cell represent imaginary longitudinal sections of the currents obtained on short-circuiting the cell and after successively inserting into the circuit the several resistance coils indicated in the upper portion of the figure. The heavy shading in the first three divisions shows the exact proportions of volume to the eye as compared with a full ampère, indicated by the broken lines. The light shading shows the proportion of pressure, which is uniformly maintained throughout. The volume in the last three spaces is indicated by the figures beneath, but is much too small to be shown to the eye on the scale adopted.

one terminal for the anode and all the negative to the other terminal as the cathode.

Figure 7 shows the result of various resistances placed in the output path of a single cell: the currents that would flow from it when its poles are united directly by a large caliber metal

wire (short-circuited), and when various resistances are inserted in this output circuit.

Figure 8 shows the output of twenty such cells connected "for surface" in parallel paths in an endeavor to increase the output. In the lower circuit resistances there is a great increase in volume, but in the higher resistances the increase is inappreciable.

Figure 9 shows the same twenty cells connected in series. Here the volume is but slightly increased in the lower resistance sections of the diagram over the same sections shown in Fig. 7. In other words, with an all metal external circuit of low resistance

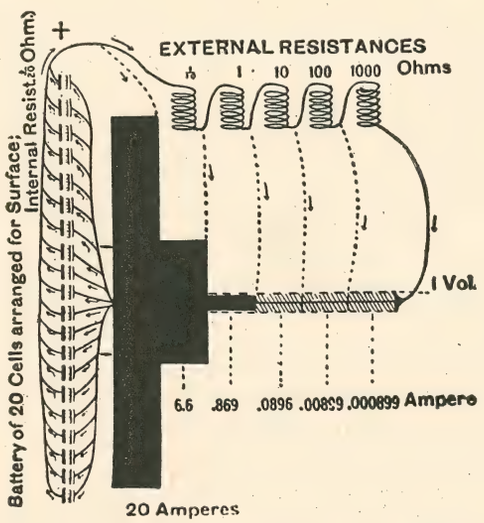


FIG. 8.—Graphic Delineation of the Pressure and Volumes of Currents from a Battery of 20 Cells Arranged "for Surface." The battery, acting as an enlarged cell, has an electromotive pressure of one volt and an internal resistance of 1/20 ohm. The first three imaginary current-sections show the proportions of volume to the eye.

we can get but little more current from twenty cells than from one cell. This is because twenty times as much internal resistance is now in circuit, the additional internal resistance of each cell. (With very small internal resistances this factor becomes of less importance.) When the larger external resistances, that of the human body from skin to skin for instance, is placed in the circuit the volume is greatly increased, as shown in the last section of the diagram.

Resistance Encountered by the Surgeon or Physician.—While the reader of these pages is referred to the proper technical works for information concerning the construction of the dynamos and storage batteries from which he obtains power and of the meter which measures it, it is essential that some idea be conveyed at this point of the electric resistances encountered in surgical work, both between the apparatus and the patient and within the tissues of the patient.

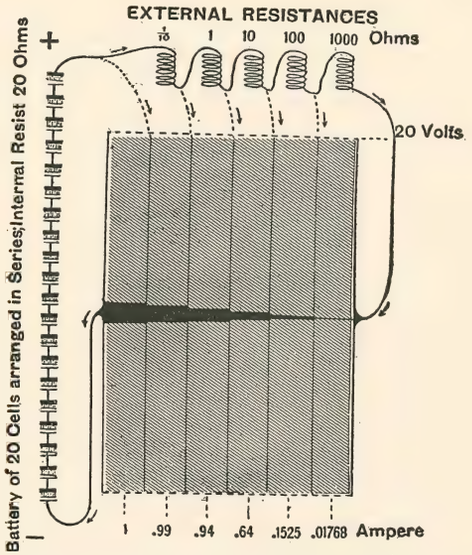


Fig. 9.—Graphic Delineation of the Pressure and Volumes of Currents from a Battery of Twenty Cells Arranged "in Series." The battery has an electromotive pressure of 20 volts and an internal resistance of 20 ohms. The heavy shading in the first five imaginary current-sections shows the exact proportion of volume on the scale of the preceding cuts. The space allotted to represent pressure is reduced, for convenience, to one-half the scale adopted in Figs. 7 and 8.

The resistance of the metallic conductors between the apparatus and the patient is very slight compared with that of the body itself, for the smallest wire that is recommended as a "rheophore" or conductor between apparatus and patient, No. 36 Browne & Sharpe gauge, presents only one ohm resistance for every 2.3 feet, as shown by the accompanying table, while body resistances between skin and skin run up into hundreds and even thousands of ohms.

Length of Copper Wire in Common Use Required to Give One Ohm Resistance. The Numbers of the Wire Refer to Brown & Sharpe Gauge.

No. 40 (an extremely fine wire, rarely used)	1 foot
No. 36 (the finest wire employed as conductor with ionization electrodes)	2.3 feet
No. 32 (a fine wire employed with small cancer electrodes)	6 "
No. 28 (the heaviest wire attached to surgical electrodes)	15 "
No. 26 (the heaviest wire attached to dispersing plates)	23 "
No. 20 (employed in annunciator and bell wiring)	100 "
No. 0 (smallest trolley wire)	2 miles
No. 0000 (trunk line trolley wire)	4 "

The resistance of the body tissues between the electrode contacts is the important factor in carrying electric power into any part of it, for definite results, such as ionization, heat or physiologic stimulation of any kind, are all directly proportional to the amount of amperage delivered within the tissues.

The human body presents a varied electric resistance, ranging from about 3000 ohms between dry metal electrodes placed on the dry palmar cuticle of opposite hands, down to several hundred ohms only when both electrodes are placed on thinner skin and have large surfaces with moist pads beneath them, the moist pads eliminating the minute air cushion between the metal and the cuticle and making the latter a better conductor. Further, if the skin resistance, which is about ninety per cent. of the body resistance, is eliminated entirely, as when both electrodes are inserted into a cancer, the resistance of the tissue between the opposite needle electrodes may be as low as 40 ohms, or even less, depending on whether the growth is in a sclerosed condition or highly vascular, the resistance being greatly reduced in the most watery growth, and depending also of course on how far the electrodes are apart.

The area of contact of the electrodes with the tissues is also most important, for a comparatively poor conductor such as the human body conducts best when the path of the current into it is wide. Large, well moistened pads should be employed therefore whenever the need of concentration is absent, as under the indifferent electrode, particularly when the active electrode is small and needle-like, making the path of entry of the power narrow at

this point. When this active pole is the drying anode, moreover, the resistance becomes greater at this point with continued duration of the current, necessitating turning on of more voltage at the controller.

Another aspect of this tissue resistance at the point of contact of an electrode carrying much power, and between the electrodes in a bipolar application, is the heat result in tissue of the concentration of flow into it by the smallness of the electrode contact. With a given number of milliamperes passing into tissue from an electrode presenting a superficial contact surface of one centimeter, any heat effect will be doubled if we reduce the contact surface to half a centimeter. To boil tissue between a positive and negative needle or needles, therefore, *the area of actual surface contact of the needles with the tissue must be small enough to present a resistance in the confined space capable of transforming the amperage used into the required heat.* In destroying a large carcinoma, for instance, a portion only of the needle electrodes is inserted at first as the current is gradually turned on, additional needles (already attached to the same trunk wire) being added as the effect of the first group is manifested in chemicothermic destruction of the included tissue; when this appears sufficient the now unnecessary electrodes first inserted are withdrawn in order that the whole power at the moment may be concentrated on those last inserted. When, on the other hand, all the electrodes to be used on the growth are inserted before the power is turned on, either a greater power will be required or else destructive effects will take a longer time. In small growths this objection to preliminary insertion of all active electrodes does not apply, as the power required will then be less and may be turned on more quickly.

Mode of Conduction and Diffusion.—All substances are either conductors of electricity, more or less good according to their molecular constitution, or non-conductors of electricity, through which it only passes by disruption of its substance or by strains, in the latter case acting as a dielectric.

Metals are the best conductors, at the head of which stands silver, though copper, the next in the list, is generally taken as the unit of comparison. Zinc wires of the same size and length present nearly three times the resistance of copper; iron over five times; platinum over seven times; and carbon about 2000 times the resistance of copper.

Conduction of electricity through metals is now thought to

be by a vibratory sway of the molecules of the metal, the cathodic stream of electrons being passed from molecule to molecule by a rocking back and forth, the electrons only passing on from the cathode to the anode.

Conduction of electricity through saline solutions, of which the living tissues are chiefly composed, is, however, by an entirely different method, more fully described in Chapter IV. Water itself is a non-conductor, the current being conducted through a solution of a salt in water by the ions of the salt in

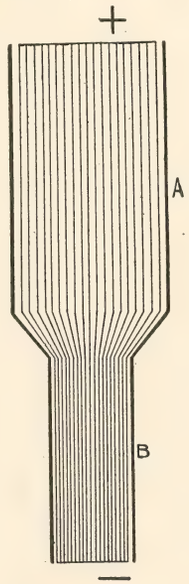


FIG. 10.—Diagram Showing Distribution of the Lines of Current Flow in a Wider and in a Narrower Conductor.

lines of ionic flow that spread throughout the breadth of the conductor, converging at points of inlet and outlet.

Considering the fact just mentioned: that a current of low voltage spreads to all points of the interior of a conductor, the importance of the density of the lines of flow at a given point below the surface of such a conductor as the human body becomes evident. Figure 10 shows how the lines of flow in a wide conductor become denser when passing through a narrower one. The drawing shows that the same number of lines of flow, the same strength of current, exists at either end of the conductor,

yet, by concentration, the current is shown twice as dense at the cathodal end as at the anodal. In reality it is four times as dense at the narrower end, for the diagram does not show the thickness of the conductor but only its width. If the smaller electrode has a width of 1 centimeter and the other a width of 2 centimeters the latter would present a conducting cross section of 4 centimeters while the former presents but one. This concentration and diffusion of the lines of flow in a wide conductor has been compared by Erb to a girl's loose hair, which may be gathered in a thin coil without changing the number of hairs.

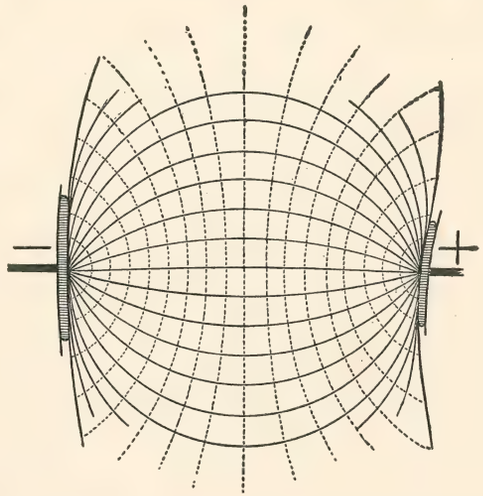


FIG. 11.—Distribution of a Current of 20 volts within the Human Body. The equipotential lines or planes become segments of perfect circles, and the lines of flow, necessarily crossing the former at right angles, become greatly curved and extend to all parts of the body in passing from electrode to electrode. The number of milliamperes traversing the lines of flow differs somewhat, being inversely proportional to the length of the lines.

The dispersion of the lines of flow when a low voltage current passes through the cuticle, with the assistance of a moist joint between the metal and the skin, is shown in the diagram, Fig. 11, which was drawn from accounts of actual measurement of low voltage current dispersion in wooden receptacles of salt water shaped like the human body.[1]

[1] *Proceedings of the Royal Society,* Vol. XXIV, p. 1. See also a theoretical discussion by Foster and Lodge, *Proceedings of London Phys. Soc.,* Vol. I, p. 113.

In studying this diagram we note dotted lines concentric with the electrode surfaces distributed throughout the electrolyte and increasing in length towards the center of the vessel, where the dotted lines become straight. Now these dotted lines really represent cup-shaped planes in the substance of the electrolyte with their concavities towards each electrode, the central plane, midway between the poles, being entirely flat.

The planes indicated in cross section by dotted lines were plotted out in the salt solution by experimental investigation during the passage of a direct current, two electrodes insulated to the tips with glass and connected with a delicate galvanometer being moved around in the solution until two points in each

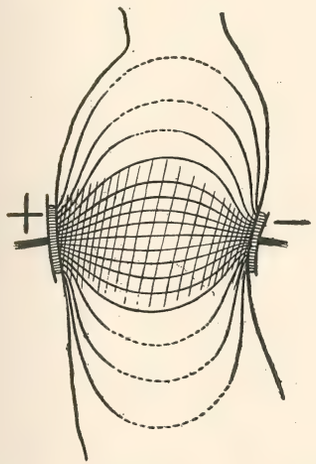


FIG. 12.—Distribution of a Low Volt Current from Electrodes of Equal Surface. (Erb.)

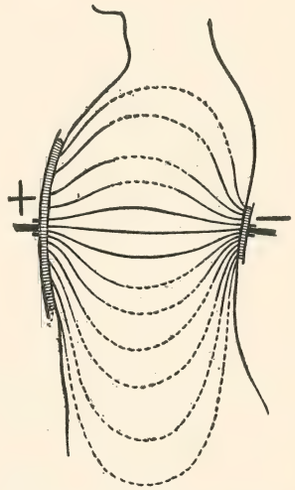


FIG. 13.—Distribution of a Low Volt Current from a Narrow and a Wider Electrode Surface, Showing Concentration Beneath the Narrow Electrode. (Erb.)

plane were found of equal potential or pressure, shown by no current flowing through the galvanometer. By painstaking care each curved plane may be thus plotted. Further investigation showed that the lines of ionic flow crossed these planes at right angles, thus dispersing to all parts of the electrolyte, and that these lines of flow convey current in inverse ratio to their length, the shortest and therefore the one carrying the most current

being of course the straight line joining the center of each electrode and crossing the center of each equipotential plane, but that it carried only so much more current than the other lines as its length was shorter than theirs.

These equipotential planes may be conceived of as steps in a staircase down which a current of water is flowing, spreading out in the curving manner that can be seen when water from a hose is turned down a broad staircase, each step having a different level of pressure. It should be noted, however, that these laws of flow become materially changed when the pressure is very great, as in high frequency currents.

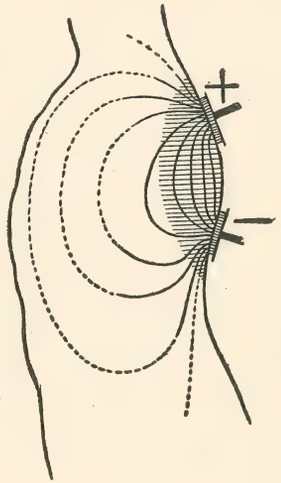


FIG. 14.—Illustrating Superficial Penetration of Low Volt Current when Both Electrodes are on the Same Side of the Body. (Erb.)

With these facts in mind we can readily plot the dispersion of the lines of flow of a low pressure current in the body with various arrangements of electrodes on the surface and in cavities as shown in Figs. 12, 13, 14 and 15.

A study of these diagrams will show the difficulties in carrying any considerable density of the lines of flow of low potential currents into deeply situated portions of the body, our only recourse being not only to properly arrange the electrodes to bring the spot into the most direct line of flow, but to increase the power and thus the number of the lines of flow turned into the whole conductor in order that a modicum of density per cubic

centimeter may reach the spot desired. This latter is greatly assisted by one electrode, the dispersing pad, being as large as convenient (which is much larger than many electrotherapeutists employ) with as perfect contact with the irregularities of the skin as possible in order to minimize skin resistance and irritation.

It should be understood that all action by low volt currents in particular, as well as by d'Arsonval high frequency currents, is accomplished by a definite density of the lines of flow through

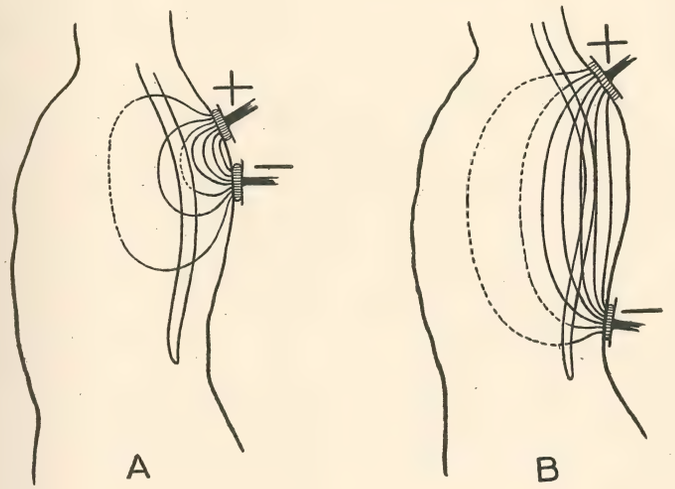


FIG. 15.—Illustrating Deeper Penetration of a Current when the Electrodes are Farther Apart, in One-sided Applications. (Erb.)

a part, whether the action be ionization, physiologic stimulation by wave action, or heat effects.

Conducting Wires and Electrodes.—Silk or cotton covered conducting cords with tips attached are usually supplied by the manufacturer of apparatus to conduct power from the outlet binding posts to the electrodes, but these soon become anything but aseptic and are best reserved for medical applications. Besides the difficulty of asepsis they are usually entirely too heavy to attach to light surgical electrodes, the undue weight causing the electrode to move or lose perfect coaptation, with added pain. Equally effective and much lighter conductors may be cut freshly for each surgical application from a spool of double cotton-

covered copper wire, the gauge of the wire being selected to suit the size of the electrode. Two or three sizes of this wire will be found useful, the smallest size being No. 36, Brown & Sharpe gauge, for attachment to small needles, small ionization electrodes, etc. For larger active electrodes No. 32 or 30 is more suitable, while for attachment to the plate backing of a dispersing pad, No. 26 is the heaviest needed and from its size more lasting on these permanent electrodes. The desirability or suitability of the sizes specified refers to convenience, lack of dragging weight, durability, or other mechanical reason and not to the question of wire resistance. The smallest wire will not present any resistance of importance compared with the tissues themselves.

After cutting a suitable length of wire with scissors, the ends are bared by shaving the insulation off with a sharp knife, and one end is securely attached to the electrode by wrapping and twisting it about the shank. The other end is securely attached to the binding post with the assistance of a small wooden plug, or the stub of a match stick if the opening is large, the binding screw being screwed firmly down, for a shock will follow accidental loosening of the conductors of the current.

Active Electrodes will be described in connection with each special surgical procedure.

Dispersing Electrodes.—The purpose of the indifferent or dispersing electrode is not only to complete the circuit, or act as outlet to the power driven in at the active electrode, but to lessen the skin resistance at this point and minimize any unpleasant sensation due to the strength of the current. Apostoli pointed out that potter's clay, employed for depolarizing purposes in physiologic laboratories, answered these purposes as a conducting joint between the indifferent electrode plate and the skin, the clay sinking into the irregularities of the skin when not too heavily covered with muslin, and making all parts of the skin surface under the electrode conduct equal portions of the current, thus broadening its path.

The author has for a number of years employed kaolin[1] instead of clay for this purpose. The advantages of kaolin in a dispersing pad are its extreme fineness of grain, permitting a fuller contact with the skin surface, and its pure white color—the latter characteristic having not only esthetic value, but making it free from the objectionable tendency to stain the clothing of the patient.

[1] Kaolin may be purchased, in quantities of 2 bushels, of the Paper Makers Chemical Co., Easton, Pa.

The pads are made of unbleached muslin for the smaller ones and of crash towelling for the larger, stitched on the wrong side, then turned and finished with a French seam, leaving an opening large enough to pour the dry powdered kaolin into them until a uniform thickness of about one inch is attained, when the opening is sewed. The pad is then ready for use after being steeped in warm water.

Useful sizes of these pads are: two round pads 7 and 8 inches in diameter, and an oblong pad 8x12 inches in diameter. These pads should be kept permanently steeped in water in a copper

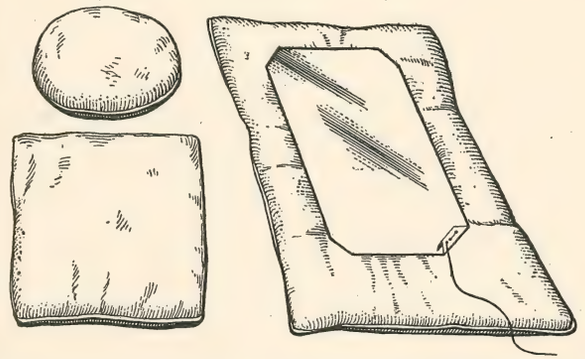


Fig. 16.—Kaolin Pad Electrodes. The thin metal plate is shown on large pad. The plate is placed on the surface of the pad opposite to that applied to the skin.

sterilizer with removable, perforated inner tray supported a half inch from the bottom, the whole being thus kept free from iron rust. In the absence of such a sterilizer of sufficient size one may use a white enamel fish boiler of the proper size, procurable in house furnishing stores. The wet pads should be warmed before use by gas or electric heat applied beneath the sterilizer.

When the pad is applied to the skin of the patient a thin metal plate is laid on the opposite side from the skin, cut from the thin lead alloy metal used formerly as X-ray protection, of a size much smaller than the pad. To this a No. 26 copper wire conductor is attached by simply threading the bared end of the wire through pin holes punctured in one corner of the plate, and made secure by taking several bends of the plate over the wire. This

attachment is, in the author's opinion, less likely to give trouble than soldered or riveted attachments to thick metal plates, as it permits us to employ the thin metal, so much more likely to conform to the surface of the body, and when broken may be repaired at once without removal from the patient.

For the lesser current powers one may use the ready made electrode pads sold by manufacturers, made of heavier metal backing and filled with powdered asbestos.

The clothing of the patient should be protected from touching the wet pad by one or more pieces of rubber sheeting.

Three General Modes in Which a Stream of Electrons Is Applied in Medicine and Surgery.—The first general class of applications of electric energy in therapeutics and surgery is that of a *direct, continuous stream of electrons through the tissues from the cathode to the anode.* This mode is practically restricted to the galvanic current in continuous flow, though the static current is also unidirectional but possesses extremely slight volume. The direct current exerts certain chemical, ionizing and phoretic actions on the tissues traversed, and when surgically concentrated produces electrocoagulation of tissues. It is considered first in this work, as its laws are of important educational value.

The second mode is the application of an *electronic stream in waves of energy, with crests which stimulate nerve and muscle into functional response corresponding to the power and suddenness of the waves,* but without chemical or phoretic action since each wave is of opposite polarity, or in a reverse direction. These are known as wave currents.

The third general mode is the transmission into the body of *a stream of electronic energy oscillating in polarity at an enormous frequency, and of a sufficient wattage to be transformed into appreciable heat of any desired degree within the tissues of the body, and at any spot selected.* These are high frequency currents.

CHAPTER III

DIRECT CURRENT POWER FOR THE PRODUCTION OF SURGICAL EFFECTS

Sources of Supply—Direct Current Mains—Alternating Current Mains—Country House Individual Lighting Plants—Battery of Dry Cells—Radio B Battery as Portable Direct Current Power—Identification of Polarity—Apparatus—Principles Underlying the Shunt Controller—Dangers from the Use of Street Currents.

Direct Current Mains.—Direct currents, called galvanic in the older medical terminology, as employed in surgery may be derived from house-lighting street mains in the central districts of our older cities and from private house lighting plants, and present a pressure of 110 volts at the lamp sockets. This initial

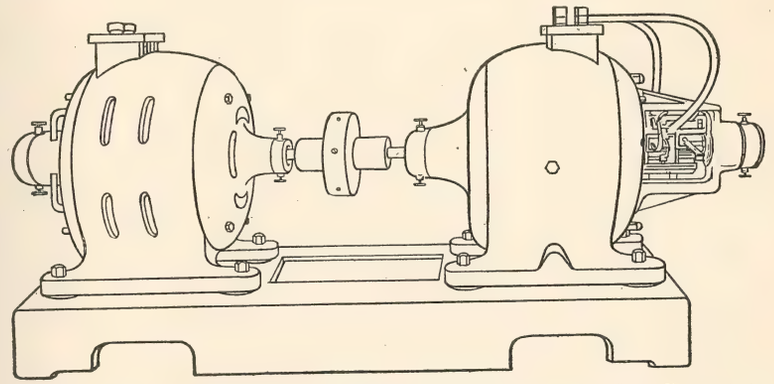


FIG. 17.—Motor Generator for Changing 110 Volt Alternating Current to 110 Volt Direct Current.

voltage, or at least 40 or 50 volts, is essential for the larger uses of this power in surgery as well as the more minute ones, on account of the considerable resistance of the body, the pressure being cut down for use by passing the current through a resistance lamp and regulated by further passage through a wire cur-

rent controller. When the mains deliver 220 volts, suitably higher lamp and controller resistances are required. The 110-volt current is that usually supplied in house lighting.

Alternating Current Mains.—When the lighting mains supply alternating current, as is the case in small cities and towns and in large cities outside the central districts, a motor-generator, Fig. 17, must be installed by the surgeon for the production of the direct current. The dynamo of this generator should yield a smooth current of 110 volts and not less than 4 amperes when

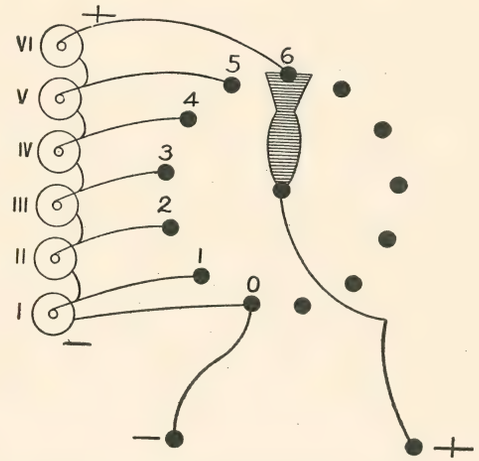


Fig. 18.—Cell Collector for Turning on Current from a Battery of Cells. The collecting arm, shown shaded, should be wide enough at contact point to touch two buttons at once while passing over them, to avoid sudden increases. But if allowed to remain on two buttons one cell will be short-circuited and used up.

it is desired to do major electrosurgical work, especially electrocoagulation with the direct current.

Country House Individual Lighting Plants.—When no current mains of any kind are available a gasoline motor-generator may be obtained, such as used in house lighting plants in country places without outside supply, though these plants are usually of but 32 volts pressure. These plants always supply the direct current if a storage battery is a portion of the plant.

Battery of Dry Cells.—In the absence of any current supply, from 30 to 40 dry cells of the standard size may be employed connected in series with a cell collector, as shown in Fig. 18,

or arranged for the full voltage of the battery with the milliamperage controlled by a controller, as shown in Fig. 19.

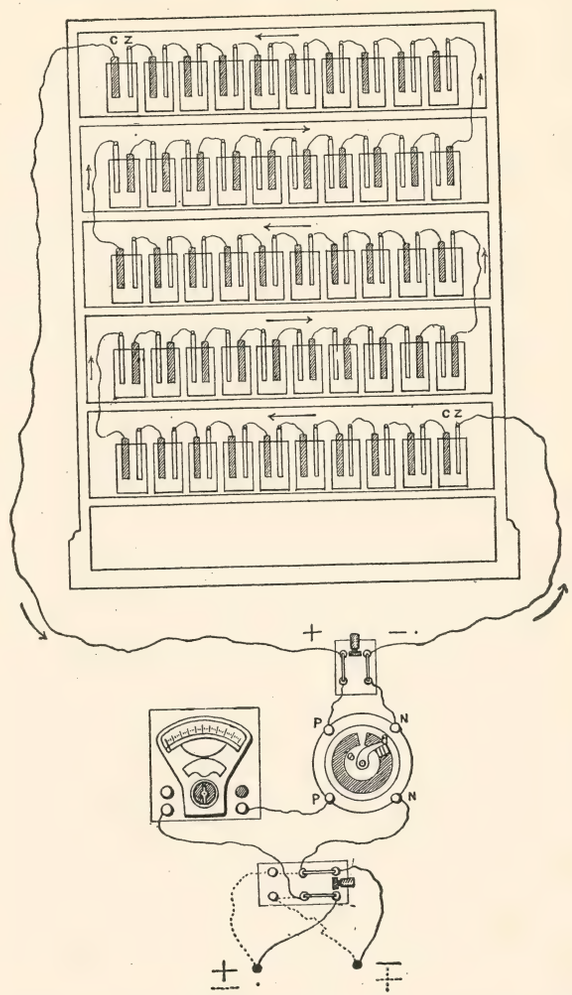


Fig. 19.—Battery of 50 Cells Arranged in Series, with Full Voltage Controlled by a Massey Graphite Controller. A meter and pole changer are shown in the patient's circuit.

Radio Battery B as Portable Direct Current Power.—When one is called upon to apply the direct current at a patient's bedside an inexpensive radio B battery of small dry cells is the most

readily obtained source of the power. These have a voltage of twenty-two and a half volts, quite sufficient for an ordinary series of applications, several amperes in fact when fresh, while two such batteries in series may be used for electrocoagulation of small growths. A split cord in the shape of the letter Y will answer for a controller, permitting a somewhat gradual increase in the current by connecting the second cord of the Y to the next cell before removing the first cord from the one preceding it. A portable meter should be placed in the circuit.

Power from direct current street mains or from the mains of a privately installed motor-generator is delivered to us at a lamp socket containing the two poles—one, connected with the anodal main, theoretically delivering the whole voltage of about 110 volts, and the other, the cathodal main, theoretically a path back to the power house to complete the circuit.[1] Fuse plugs are inserted in the outlet mains back of the lamp socket designed to melt and break the current if an amperage in excess of that proper is accidentally turned on by "short-circuiting" (or allowing the metal wires to touch each other back of the protecting lamp resistance).

Identification of Polarity.—Whenever a new socket is used to draw power the polarity of its terminals should be tested, either directly by testing the wires attached to a plug inserted in the socket, or at the patient's terminals of the apparatus.

To test the polarity of the lamp socket proceed as follows: With a suitable length of double-conducting cord attached at one end to a plug, before inserting the plug, bare the other ends of the wires in the cord and separate them about an inch and a half so that they will not touch each other and blow a fuse. Now insert the plug in the socket and bring the bared end of the wires in contact with a piece of wet litmus paper laid on a glass surface: the positive pole or anode will be indicated by a red color. Or, carefully insert the separated ends of the wire in a glass of tap water: the negative pole or cathode is indicated by twice as much gas formation as the anode, the dissociated molecules of water yielding up two volumes of hydrogen at the

[1] There is reason to believe that the poles have been misnamed, and that the cathode is the pole from which it flows. But this question is purely academic. A miller may operate his mill perfectly and with complete control of his water power from within the mill, without knowing whether the power supply was a stream from the east, with an undershot wheel, or a stream from the west, with an overshot wheel.

cathode to one volume of oxygen at the anode. The addition of a few granules of salt to the water makes the demonstration of the latter test more spectacular, for the lessening of the resistance by the salt electrolyte allows more current to flow through it. Polarity tests should be made at the patient's terminals also on using all new apparatus to make sure of the correctness of the wiring at the factory as well as after repairs have been made.

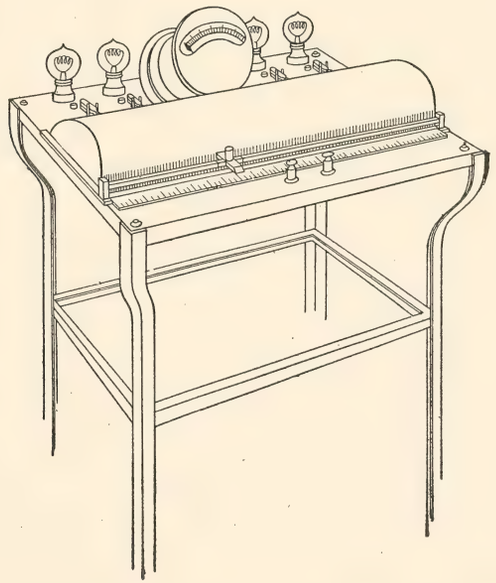


FIG. 20.—The Massey Galvanic Table. A wire shunt controller for administering either the smallest or the heaviest galvanic current without shock.

After testing the supply wires as described, the plug should be removed from the socket or the current otherwise turned off before connecting the supply wires finally to the apparatus.—the identified anodal wire to the inlet post marked + or P, and the cathodal wire to the inlet post marked — or N.

Direct Current Apparatus.—All surgical applications of the direct current, as well as low-frequency wave currents except those produced by the Morse Generator, should be made by a shunt controller apparatus of the general type shown in Fig. 20, such apparatus being indispensable when massive currents are

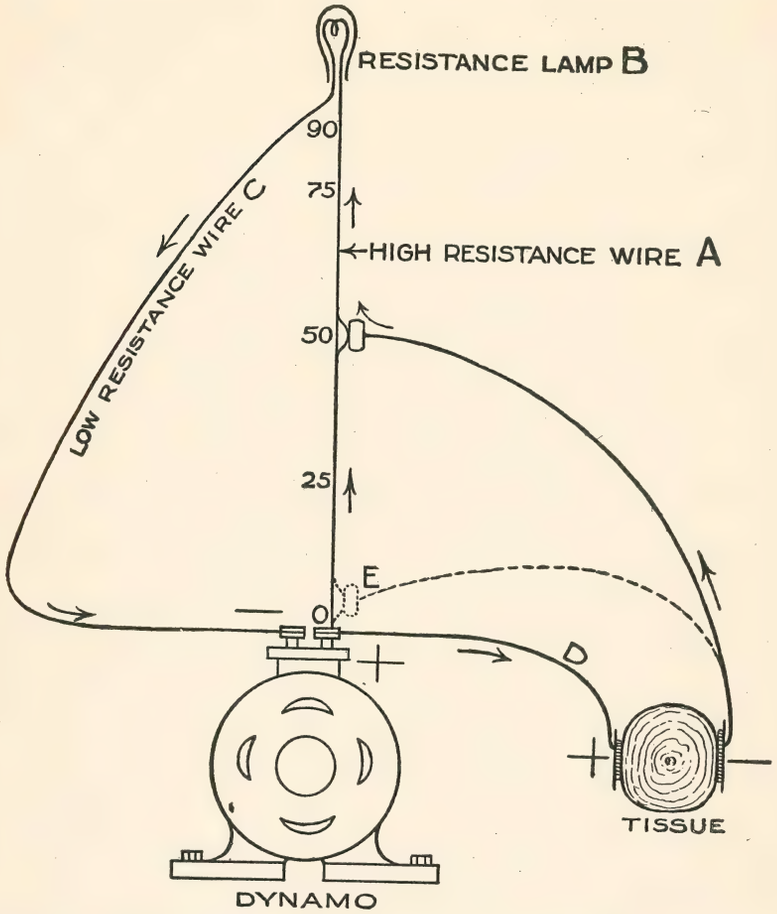


FIG. 21.—Diagram Showing the Principles Underlying a Shunt Controller. The high resistance wire in the resistance coil is shown for convenience as an upright straight wire, A, with a resistance lamp B in circuit with the power mains of a 110 volt current. About 10 volts is consumed in the lamp and the remainder distributed along the wire, as shown. The slide, E, taps this voltage as it slides up from O.

used because of its capacity for carrying heavy volume. By reason of the fact that a shunt controller controls the pressure as well as the volume, it is also best for the application of small currents in painful spots. It consists of a large resistance drum in circuit with the mains through a resistance lamp or lamps.

The drum must be large in order that many feet of a high resistance wire may be wound on it to permit a gradual turn-on of the current in the patient's circuit. When more than one lamp is used they are in "parallel circuit," and not "in series," that is, they act as gates alongside each other in a fence through which the power flows when one or more is opened, each gate when open facilitating the flow (or lessening the resistance). When we wish to use only a little power we turn on one lamp or open that "gate"; when we wish to use heavy power we turn on all the lamps and also at times replace lamps having small filaments with ones having larger filaments, permitting a maximum of power to flow through them. The lamp and the high resistance coil are in series, that is: one after the other by joining a terminal of each together, the outer terminals of the combination being connected with each main. As a consequence, considerable power flows through the combination and directly back to the mains without passing through the patient or the meter. The meter should therefore not be placed in this main circuit, for if it is in it instead of in the patient's shunt circuit it will give false readings because of showing this wastage current as well as that passing through the patient.

Attached to this resistance coil wound on the drum is a provision for tapping its power at various pressures to supply the side path or "shunt" path through which power flows to the patient as described below.

The principles underlying the shunt controller are depicted in Fig. 21. If the power from the lamp socket is turned on a resistance composed of the lamp filament and a long wire of high resistance joined end to end, or in series, by connecting each main with an end of the combined conductor, the current will flow through the lamp and wire, and its voltage will be evenly distributed along the lamp filament and the high resistance wire as shown in the diagram. If, now, one electrode in the tissue be connected by the low resistance wire D to the beginning of the high resistance wire A and the other tissue electrode be connected by low resistance wire with the slide E (made to slide along the high resistance wire), a second path for the current will be opened through the tissue or patient *when the slide is pushed up along the high resistance wire* A, the patient receiving the voltage tapped from the high resistance wire by the slide as it passes along. When the slide reaches the figure 50 the voltage in the patient's circuit will be about half of the whole, or 50 volts.

When the slide is at the upper end of the wire A about 90 volts will be turned on the patient's circuit out of the 110 volts in the mains, the remaining 20 volts having been absorbed by the high resistance wire and the lamp filament. Increasing the size of the lamp filaments or turning on others "in parallel" will increase the voltage in the patient's circuit slightly, while in some motor-generators provision is made for increasing the voltage of the current produced by the dynamo to as much as 135 volts.

In operation, the slide abstracts voltage for the shunt or patient's circuit from the current passing through the high re-

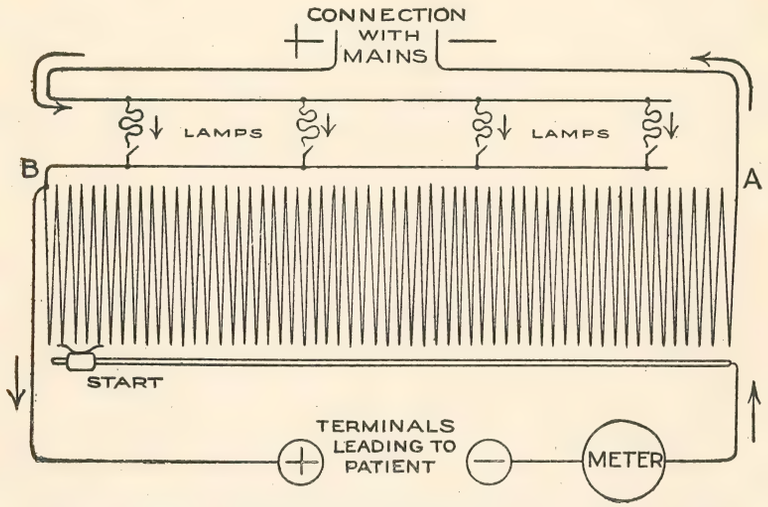


Fig. 22.—Diagram of the Wiring and Circuits of a Shunt Controller.

sistance wire. At whatever position it rests, therefore, the total voltage or pressure at the lamp socket will be divided between the all-wire-and-lamp-filament circuit and the patient's circuit in inverse ratio to their respective resistances. The resistance of the lamp-wire circuit is a fixed amount and unchangeable except by changing the lamp or adding additional ones alongside. In the patient's circuit we may lessen the resistance and thereby increase the power used at any given position of the slide by increasing the number or size of the electrodes in contact with the tissue, or by bringing them closer together.

In the apparatus as actually made, the high resistance wire of the controller is wound on a drum made of insulating ma-

terial for convenience, for it has to be many feet in length to present enough resistance. By coiling it around the drum the whole length of the wire is brought into a convenient compass, though this causes a slightly less smooth increase of power as the slide passes from turn to turn of the coiled wire. Figure 22 presents a diagram of the apparatus as actually wired.

Dangers from the Use of Street Currents.—There is unquestionably some risk in using a street lighting circuit for treatment if the line wires are strung overhead in the streets, one element of risk in this case being the possibility of an arc-light wire of high voltage falling on the low volt house-lighting wires. No instance of this accident is known to the author. The remedy is the use of a motor-generator for producing the direct current for surgical or medical use and the Morse wave generator for the alternating therapeutic current, as such an accident would be impossible when either generator is used since these instruments are "ground free," or without metallic connection between the generator and the street current, an insulating washer being placed between the motor and dynamo of the motor-generator and insulation and air spaces between the two circuits in the Morse instrument.

The accidents related in the literature and in one instance, in the daily press, were of a different nature. If one holds in the hand a wet electrode attached to a sinusoidal machine operating under the A.C., and at the same time touches a gas pipe with the other hand an unpleasant shock will be felt. This is due to a condenser discharge through the body from the large capacity condenser, consisting of the A.C. transformer and its charge, as one side of the condenser and the gas pipes as the other, the intervening earth being the dielectric of the condenser. *When the electrode surface of the body is large and making perfect contact,* even one electrode surface only, as when a patient is partly immersed in a bath, with the water of which the street current is in metallic connection, the completion of the condenser circuit by *some part of the body, outside the bath, coming in contact with a gas or water pipe,* may produce a shock great enough to cause death.

The same accident may happen when the current is in a motor only, such as a vibrator, which comes into contact with the water at a time when a part of the patient's body outside the bath comes into contact with a good ground.

The remedy in the latter cases is either to have earth-free

currents only as described, or to remove the possibility of grounds from the bath and its vicinity. This requires that metallic connection between the bath and the plumbing of the house be severed and rubber or wooden pipes be used, and the removal of all gas and water pipes beyond reach of one in the bath. It may be added also that electric light fixtures should not be within reach of one in a bath, as a serious shock may be received by the hand coming into contact with a live wire of even these low volt currents when the body has a broad contact with earth through the water of the bath and the metal piping.

CHAPTER IV

CHEMICAL EFFECTS RELEASED WITHIN LIVING TISSUE BY DIRECT CURRENT POWER

Ionic Dissociation by Water—Electrolysis—Interpolar Action—Polar Action in an Electrolyte—Experimental Work in Surgical Electrolysis—Phoresis—Cataphoresis—Anaphoresis.

The student having mastered the subject of direct current power supply to the patient's binding posts in the preceding chapter must now turn to the patient's circuit itself, beyond the binding posts of the apparatus.

The first thing to learn in handling the apparatus is to make sure that *the controller slide is at the starting point,* or point of no current, before attempting any use of it. The formation of this habit will save future patients many unnecessary shocks. The second good habit to form is to refrain from bringing the conducting wires, cords, or other metal parts in contact with each other when the controller slide shows power turned on, as this will short-circuit the power through the meter and risk harm to its mechanism. One should also see that all binding posts and other connections are *tight* and *firm* so that the circuit will not be accidentally broken with more or less shock to the patient.

Before applying direct current to tissue it is well to test its action in a solution of common salt in water, as described in the polarity test, page 26, for within the cuticle the human body is a more or less homogeneous solution of many salts and other electrolyzable compounds in water. This brings us to the important subject of ions and ionization.

Ionic Dissociation an Effect of Solution in Water.—Salts are now regarded as molecules formed by the union of a metal ion and an acid ion, whether the one or other of the component ions be simple charged atoms, as in sodium chlorid, in which the sodium is a cation and the chlorin an anion,[1] or complex mole-

[1] As a key to the names of the ions one should remember that they are named for the poles that they *seek,* though they have charges of opposite character to their names. This opposite charge is the reason they seek the

cules, as cocain hydrochlorate, in which the complex ion cocain is a cation and the hydrochloric acid an anion. All molecules are divisible therefore into two ions (if they be capable of electrolysis), whether simple unions of two atoms or unions of many atoms joined together by their electronic constitution. It is, in fact, the number of the electronic components of each atom or group of atoms forming an ion, as stated in Chapter I, that dictates whether it is possessed of a deficiency charge and therefore a cation or an excess charge of electrons and therefore an anion. The salt molecule itself exists by reason of these opposite, reciprocal, charges of its ions, chemical affinity being but an older name for ionic affinity: the almost irresistible force that compels oppositely charged ions to join each other and remain joined tightly as long as the molecule is dry.

But a salt is no longer a closely knit union of two ions when it is dissolved in water. As soon as solution occurs the electronic bond weakens and large numbers of the ions become dissociated from their partners, *retaining, however, their ionic charges,* else in the body, which is but a salt solution, the phosphorus atom, for instance, freed of its charge, would immediately attack the oxygen of the tissues with destructive effect. The presence of the electrolyte in the water serves to dissociate some of the H_2O molecules also. Ordinary water contains free ions at all times therefore, due to the impurities dissolved in it from the earth, air, etc., held in solution and themselves partly dissociated.

Dissociation is therefore a most important property of water, by which the oppositely charged ions of a molecule dissolved in it tend to separate entirely or else cling together with less force. And the extent of the dissociation of the dissolved substance is greatest when the contact between the water molecules and dissolved molecules is greatest, in other words, when the solution is most dilute.

All chemical and physiologic phenomena are due to reactions between ions. Life itself can only be maintained by their free movements, and death also calls for their free play in the presence of water in reducing complex bodies into simpler compounds. Definite concentrations of ions on either sides of membranes result, through the laws of osmosis, in the basic processes

pole. Sodium, for instance, is a cation because it seeks the cathode, to which it carries a positive charge.

underlying growth, nutrition and decay as well as in the production of function.

As ionic action at ordinary temperatures is impossible in the absence of water, the real meaning of a desert or of a waterless planet is evident.

An electric current driven through a water solution *is conducted only by the ions contained in the solution.* The amount of cur-

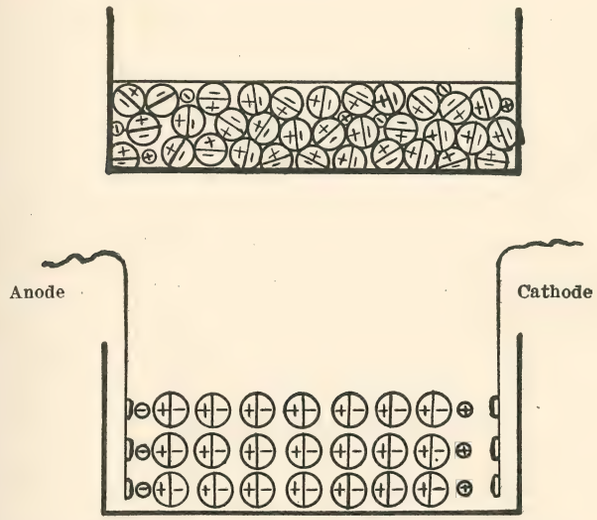


FIG. 23.—Diagrams of Electrolysis. The upper diagram shows a solution of an electrolyte in water when no current is passing through it. It will be noticed that some of the molecules of the salt (the large round figures made up of two ions associated together) are broken up or "dissociated" by the mere action of the water, the ions being free in the water. There is no special arrangement of the molecules. The lower diagram shows what happens when a current is sent through the solution. The — marked cations seek the cathode and the + marked anions the anode.

rent of a given voltage sent through the solution will depend on the degree of the dissociation of the molecules of the dissolved substance and of the water itself into ions, and the valency, or number of electrons, carried by each ion. Plurivalent ions carry electric charges proportional to the large number of electrons they consist of. Complex ions, such as those of the organic compounds, carry charges also proportional to their total constituent electrons. The dissociation of a complex molecule into

ions does not mean its decomposition into its ultimate atoms. The cocain ion in cocain sulphate or muriate, for instance, is not decomposed into the atoms of which it is composed either by ionic dissociation in water or electrolytic phoresis but merely detached from the acid ion as a cocain ion. This is true under the anode and in all parts of the circuit until it reaches the cathode (which never happens in cocain ionization or cocain phoresis) where true decomposition doubtless occurs.

In consequence of the dissociation of molecules by water a watery solution of such substances contains three kinds of particles: neutral or undissociated molecules, anions and cations, mixed together without special order or arrangement. What, then, happens when we pass a direct current through such a solution of common salt, as indicated at the beginning of this chapter?

Electrolysis.—On inserting the wires of the apparatus at opposite ends of the glass or other non-conducting receptacle containing the salt solution and turning on enough power to get readily visible effects, say 50 milliamperes, there will be an instantaneous readjustment of the whole contents of the solution, the free ions will seize partners of opposite charge, even undissociated partners of other charge, and temporarily dissociating them, will whirl around, lose them to other partners back of them of the same sign, and then whirl back for more partners, on their way to the pole they seek—the sodium cations finally reaching the cathode after many exchanges of partners and the chlorin anions the anode. On reaching the cathode wire the sodium and hydrogen cations lose their charges and become atoms in a state that was formerly called "nascent" or new born, attacking surrounding substances with special vigor, which is not great for these atoms. The chlorin and oxygen ions on reaching the wire anode likewise give up their charges, and in their nascent condition attack surrounding substances and even the wire itself with a vigor proportional to their great chemical activities (Fig. 23).

The late Sir Lewis Jones, of London, has given a striking word picture of an electrolytic solution, which he compares to a ballroom containing dancers united in couples who represent the undissociated molecules, and a certain number of isolated ladies and gentlemen who represent the dissociated ions. If at one end of the room there is a large mirror, and at the other end of the room a buffet supplied with champagne and good cigars,

and the ladies make their way by changing partners to the mirror while the men go to the buffet in the same way, the room presents a close analogy to an electrolytic solution at the moment when the current is passing.

Interpolar Action in an Electrolyte.—Now it should be understood that direct currents produce ionic interchanges along the lines of flow on all occasions when they are passed through the body, in direct proportion to the amperage of the current, whether the current be applied by needle electrodes, small or large metal electrodes or pads of any kind or size, and that the interchanges and forced transit of the ions *are equal in amount at all points of the circuit between the electrodes,* though the amount passing through a given cubic centimeter deep in the tissues of the body conductor will depend on the concentration of the lines of flow at that spot, being inverse as to the breadth of the conductor as a whole in that part of the circuit and direct as to the strength or amperage of the current (see page 16). A glance at the diagram on the page referred to will show the great dispersion of the lines of flow at only moderate distances from the electrodes. This indicates that if we wish to reach a deep spot, as the unstriped muscle of the intestine, with even a small concentration of the ionic flow or a direct current sinusoidal wave, we must employ heavy current power at the electrode points of inlet and exit.

There has been doubt among electrotherapeutists as to the possibility of remedial action in this middle region between the poles, but the fact that equal ionic interchanges occur in all parts of the circuit, being only spread out and weakened when the conductor is wide, means that ionic passage through the membranes of cells and other structures occurs at all points in accord with the concentration of the lines of flow, necessarily involving an alteration of physiologic processes, even though these are slight with the current power usually employed. The results must be due to the forced and artificial flow of ions from structure to structure, for with the brief duration of these applications no external ions could reach the deeper parts, the ionic changes in this situation being those of the body fluids near by, the semi-dissociated condition being probably the constant state of the molecules of body fluids, the molecules being completely dissociated into ions and reassociated perpetually during life in the chemical changes of anabolism and catabolism.

Polar Action in an Electrolyte.—We have seen that the ions

in an electrolyte through which a direct current is passing seek the poles after which they are named carrying an electric charge which suspends their atomic activities, and that they give up their charges on reaching the poles and revert to their nascent condition. The necessary result, of course, is a region of chemical activity at each pole determined by the nature of the atoms freed there, and that the chemical activities at each pole will be in marked contrast to each other. Since some chemicals are liable to attack the substance of the electrodes themselves we must use unattackable electrodes if we wish to separate pure chemicals; for instance, carbon cathodes, as in the electrolytic separation of caustic soda, etc., commercially at Niagara Falls. If an attackable anode is used ions eroded from the electrode are driven into the body beneath the anode. If this is not desired we should employ platinum or gold. The chemicals released at the cathode in the human body do not usually attack the cathode of an attackable metal with the exception of aluminum, which may be ionized and dispersed from the cathode at times.

Experimental Work in Surgical Electrolysis.—To emphasize the importance of the metal forming the anode, perform the following experiment: Place a piece of absorbent cotton on a glass plate or other nonconducting surface and saturate it with salt water. Under one end of the wet cotton insert the end of a fine wire connected with the cathode of the apparatus, allowing sufficient bared wire to make broad contact. Select a bright steel knitting needle or other small object of iron or steel, and connect it to the anode binding post by wrapping the bared end of a piece of wire about one end of the needle.

With the cathode electrode in place, press the free end of the knitting needle in the wet cotton at some distance from the cathode and turn on about 100 milliamperes of power. A dark stain will appear at once with this amount of current beneath the knitting needle, progressively increasing in size and depth each moment. This stain is made by ferric ions detached from the needle and uniting with chlorin and oxygen ions that approach the needle as the ferric ions are driven from it. Examination of the needle a few moments later will show it roughened slightly and losing its brightness. No perceptible amount of oxygen or chlorin gas will be found to rise from the steel needle electrode surface, for the metal is so attackable that all the released anions are absorbed by the ferric ions. At the cathode, on the contrary, a frying sound will be heard with this

amount of power, due to minute bubbles of hydrogen gas escaping through the meshes of the cotton.

A similar test of electrolysis of the living human tissues is best made by using a very fine steel needle in a fleshy mole of the skin of sufficient size to show the action readily to the eye. This application should be unipolar, that is: the active needle only used in the mole and the other pole attached to a plate backing of a large dispersing pad on a distant part of the body.

Selecting the anodic action of the so-called positive pole for the first test, we connect the dispersing pad with the cathode or negative binding post and the active needle electrode to the positive binding post. With the controller slide showing no current, we gently insert the steel needle into the center of the mole and, holding it steadily to prevent the pain of current breaks, we turn on one to two milliamperes. In a few moments a brown discoloration will show about the place of puncture, due to the ferric ions from erosion of the needle. The action should now be stopped, as it is evident that we risk staining the tissues permanently as the ferric ions discharge their charges when uniting with tissue oxygen, phosphoric acid, chlorin, etc., forming staining molecules. This experiment shows that a steel needle should not be used as an anode in the tissues in a situation, at least, where staining is objectionable.

Taking a fresh, equally fine steel needle and making it the cathode with the dispersing pad the anode, a similar technic will show no staining. If the needle is inserted in the spot where the ferric ions were deposited these will soon be seen to be loosened by a tiny ebullition of froth, consisting of hydrogen bubbles in a solution of caustic soda, there being distinct evidence of increased moisture. When the needle is inserted near the base of the mole, parallel and near the skin surface, the hydrogen will collect beneath the cuticle of the mole, making the latter appear pearly in color. This cathodic technic is exactly that described in the chapter on Dermatology as the classical method of destroying moles and warts. The current is to be kept up, with needed changes in the position of the needle (the changes to be made only with the power turned off), until the whole of the mole is pearly in color down to the derm, but the power must be turned off before the skin base itself or the surrounding skin is destroyed else a permanent scar will result.

At the end of this experiment the steel needle will be found to be entirely unchanged, the base ions of the human electrolyte

being unable to attack it, and there is consequently no reason whatever to use any other material than steel in these minor surgical uses of cathodic electrolysis if one is sure that his apparatus is properly wired and that he is not using the anode by mistake.

When one uses the anode in electrolysis, as in the treatment of cavernous angioma or the gold wire treatment of aneurism, where we desire a drying, coagulating, hemostatic effect, an unattackable electrode of platinum, gold or carbon must be employed; though on bleeding mucous membranes the addition of the zinc ion by the use of a zinc-mercury anode greatly increases the hemostatic effect. Such use of zinc or other foreign ions similarly driven in converts the process, however, into an ionization rather than electrolysis.

The word "electrolysis" in surgery should be reserved and applied only to applications in which the cathode is employed as active pole without foreign ions on it, or when the anode as active pole is of unattackable metal and also unsupplied with foreign ions. All other applications with diffusible foreign ions or attackable anodes should be described as "ionizations."

To recapitulate: The cathode, or so-called negative pole in electrolysis, produces an alkaline, soft, watery lesion with evidence of caustic soda action but no hemostatic effects. On a larger scale than depicted in the experiment, especially on hemorrhagic mucous surfaces, it favors hemorrhage and may aggravate such a tendency. It causes hyperemia and thereby quickens local nutrition.

The anode, or positive pole, in electrolysis (with unattackable electrodes) produces a hard, dry, acid lesion, and is distinctly hemostatic, but not quite as hemostatic as when zinc or zinc and mercury ions are employed. Its immediate action is ischemic and sedative.

Phoresis.—The word phoresis, from the Greek root to flow, refers to the flow of ions in both directions, and also to the interesting fact that water molecules themselves in an electrolyte flow towards the cathode when a current is passed through it. This is a very conspicuous action of the direct current of any magnitude when passing through the body, even two or three milliamperes concentrated at the point of a fine needle, as described in the electrolytic destruction of a mole in a previous paragraph, showing increased moisture about the cathodic needle point in a few minutes. With more current power passed through

a cotton-covered ball cathode in the vagina, for instance, the cotton becomes distinctly more moist (and a better conductor if insufficiently moistened) after a few minutes flow of 50 milliamperes, water having been abstracted from the tissues; while if the experiment be made with the vaginal electrode as the anode and similarly covered with moist absorbent cotton the cotton will come out drier.

This physical property of water phoresis towards the cathode helps to explain why this pole is most effective in dilating strictures of the urethra, nasal duct, esophagus, etc., materially assisting the soapy ions of sodium and hydrogen developed at the same time.

An equal number of water molecules is driven from the tissues beneath an anode, or from its moist covering, hence a small metal anode without moist covering causes such drying of the tissue in immediate contact with it, with large surgical amperages, that we are impelled to increase the voltage turned on at the controller after a few minutes in order that the desired amperage may be maintained in the circuit.

Cataphoresis is therefore the flow of the cations of water *from the anode towards the cathode.* It describes accurately the ionic dispersion of drugs the base ion of which we wish to diffuse into a part from beneath the anode, or of metal ions from the electrode itself.

Anaphoresis, conversely, is the dispersion of acid radical anions into a part *from the cathode towards the anode.* It is important in medicine also, as well as in certain local applications, for the halogens (iodin, chlorin, etc.) are driven in from the cathode, as well as certain complex ions, such as the quinin ion from its sulphate and muriate; the salicylic ion from salicylate of sodium, etc.

Notwithstanding the particular value of these words cataphoresis and anaphoresis, and of the operator knowing his chemistry and employing the proper pole in surgical and medical work with ions, it is not usual at the present time to make much use of either word, but, for the sake of clarity, to speak of the ion itself as the remedy and the process of diffusing it from the proper pole as ionization.

CHAPTER V

IONIZATION, OR THE DIFFUSION OF REMEDIAL IONS IN MEDICINE AND SURGERY

Foreign Ions—Quantity Diffused—Depth of Penetration—Behavior of Foreign Ions after Diffusion into the Body—Sterilizing Ions—General Surgical Uses of Sterilizing Ions—Conditions in Which Sterilizing Ions Would Seem to Be Indicated—The Magnesium Ion—Medicinal Ions—Technic of Medicinal Ionization—Sclerolysis—The Lithium Ion—The Salicylic Ion—The Quinin Ion—The Iodin Ion.

We have heretofore considered primarily the ionization by water of the various chemical substances of which the body is composed; the constant instability of the reciprocal unions of these ions during metabolic processes; and the artificial and forced flow of body ions when a direct current is sent through a portion of the tissues. In medicine and surgery the word "ionization" is now applied in a narrower sense than this, and refers to the *driving of foreign ions into the body.*

It should first be understood that foreign ions of some kind are always driven into the body whenever a direct or galvanic current traverses it, since conduction in liquids is by traveling ions only. When we think we are using plain water on the electrode pads we are really driving in at the anode the base cations of the dissolved substances in the water that render it a conductor, and the acid anions at the cathode. Alternating currents of all kinds are similarly conducted through the body by the body ions, but the flow of the ions in either direction is for an exceedingly brief moment, and is immediately negatived by a similar flow back to the point of departure. No lasting ionization can therefore be done with alternating currents. In the static currents we have a true unidirectional flow and they are therefore theoretically capable of ionization, but their amperage is so insignificant that no material ionic diffusion is possible with them.

The subject of ionization of the body with foreign ions received much attention in America during some years subsequent to 1893 under the name of cataphoresis, since cations were mainly employed, much being written on the subject by William James Morton, M. A. Cleaves, the author of this work and others, but comprehensive treatment of the physics of the process was first presented before French physical and medical bodies by Professor Stephane Leduc, of the School of Medicine of Nantes, and in a monograph since published;[1] and later by the late Sir Lewis Jones, of St. Bartholomew's Hospital, London.[2] The interested reader is referred to these writers for a fuller consideration of medicinal ionization than is possible in these pages.

Foreign ions are diffused into the body in direct proportion to the milliamperage of the current and the time of its flow, and the amount diffused has no relation to the strength of the solution of the substance above about 2 per cent. In other words, a solution stronger than 2 parts to 100 parts of water (which is usually the strength at which the molecules of a substance is most fully ionized by water) will not cause more ions to be diffused than the weaker solution when similar current power is used.

When diffused into the body, foreign ions necessarily displace an equal valency of the body ions inwards at the active pole, and outwards, into the dispersing pad, at the indifferent pole.

The fact that these foreign ions are most intimately diffused into the substance of the smallest anatomical elements, the tissue cells themselves, is a most important fact in contrast to grosser local diffusions of dissolved substances by hypodermic injection, when only intercellular diffusion is possible. In other words, ionization produces *intracellular* diffusion at once, while mechanical insertion of ions into the tissues can only be *intercellular* at first, becoming intracellular only by the aid of subsequent osmotic interchanges. The difference between this direct local medication of the cells of a part by ionization and the flooding of the body by the ions via the alimentary tract in order that the local part may reach a similar concentration, is eloquently

[1] "Electric Ions and Their Use in Medicine," by Professor Stephane Leduc, translated by R. W. Mackenna, Rebman, London, 1908.

[2] "Ionic Medication," by H. Lewis Jones, P. Blakiston Son & Co., Philadelphia, 1915. See also "The Theory of Ions," by William Tibbles, Rebman, New York, 1909.

emphasized by Leduc, and should appeal to all practitioners of medicine.

The Quantity of Ions Diffused.—The following table, after Leduc, has been calculated to show the amount in milligrams of each substance liberated by one coulomb of electricity (1 ampere for one second) in the first column. The second column shows the calculations of the amounts diffused by one milliampere in one minute. The third column gives the relative velocities of different ions, as measured by Leduc for the human body. The actual measurements within the body were found to show velocities that differed somewhat from those found by other observers under purely chemical conditions of experiment.

TABLE OF QUANTITIES OF IONS DIFFUSED BY A GIVEN CURRENT, AND OF THE RELATIVE SPEED OF IONS

	Milligrams per Coulomb	*Milligrams per Milliampere Minute*	*Relative Velocities* (Leduc)
Anions:			
Bromin	0.82	0.049	0.9
Chlorin	0.367	0.022	1.0
CO_3	0.32	0.019	0.84
Hydroxyl	0.18	0.01	1.27
Iodin	1.31	0.078	1.16
NO_3	0.66	0.04	0.7
PO_5	0.26	0.016	1.18
Salicylic Acid	1.4	0.085	....
SO_4	0.5	0.039	0.58
Cations:			
Ammonium	0.06	0.003	1.56
Calcium	0.206	0.012	0.5
Cocain	3.0	0.18	0.59
Gold	0.678	0.04	0.22
Hydrogen	0.01	0.0006	0.88
Lithium	0.07	0.004	0.28
Magnesium	0.115	0.007	0.5
Mercury	1.03	0.062	0.8
Potassium	0.4	0.024	1.0
Quinin	3.9	0.234	0.62
Radium	1.13	0.066	...
Silver	1.1	0.06	0.5
Sodium	0.23	0.014	1.6
Strychnin	3.4	0.207	...
Sulphur	0.16	0.01	...
Zinc	0.33	0.02	0.6

The Depth of Penetration of Ions.—With the surgical ions, zinc, copper, silver, etc., the depth of penetration into tissue may

be estimated by the eye, the depth of the staining being an accurate indication. Thus we know that zinc ions from a zinc needle produced by 20 milliamperes of current will be radiated about 1 centimeter in all directions from the needle in an hour. This will be shown by the white color on the skin surface. In the softer subdermic tissue the zinc ions will extend somewhat farther. In granulation tissue they will extend at least twice as far with the same current and the same time.

Referring to the table above we find Leduc places the relative velocity of a zinc ion as 0.6 compared with potassium. To ascertain the depth that iodin will be driven by the same current of 20 milliamperes in one hour, we note that the relative velocity of iodin is given as 1.16, or about twice that of zinc. With the current strength and duration given, iodin should penetrate 2 centimeters or possibly more in average tissue in an hour. Similar calculations can be made for the other ions mentioned in the table whose relative velocities are given.

Valuable as ionization is in its local surgical applications to diseased tissue within one and two centimeters of the electrode, it is evident that these figures do not sustain a hope often expressed that we may flood the cells of a deeply seated joint or nerve, or of a whole region of the body by currents within the endurance of the patient when sent through the skin. But the one and two centimeters of direct diffusion may be of great medical as well as surgical use, particularly when it is understood that, whatever the depth penetrated, a larger proportion of the molecules formed by the ions by union with body anions are, at the termination of the current flow, in intimate union with the tissue elements themselves rather than merely in the plasma and intercellular spaces as would be the case by a mechanical injection into the part, and that it has been proved that the physiologic action of the substance sent in as an ion—that of cocain, for instance—persists for a longer time in that particular locality, and is not so soon lost in the general circulation as when mechanically administered.

Behavior of Foreign Ions after Diffusion into the Body.—When a foreign ion is diffused into the tissues it does not need to reach the opposite pole on the other side of the body to give up its charge and be reduced to its atomic or molecular activities. It is reduced by the opposite ion as soon as it encounters it in the tissues or body fluids, though doubtless the actual ions themselves proceed onwards in the circuit towards the opposite pole

by a continual union-and-release action with opposite ions encountered moving in the reverse direction, the effect being the outward production along the lines of current flow of new molecules that retain their place more or less, though being made up from moment to moment of ever changing ionic constituents.

Since the foreign ion is thus "reduced" by union with an opposite ion of the tissue substance or fluid as soon as diffused into a part, it follows that we obtain a local action in a part, not of a free ion, but of a *chemical substance,* and that the effect must vary and be dependent on the action of the chemical thus created where we want it to be, with actions as varied as the chemicals themselves.

The chemical effects of molecules thus resulting from diffused foreign ions are divisible into two widely differing groups: Sterilizing Ions and Medicinal Ions.

STERILIZING IONS

All metals of the alkaline earths which give an insoluble precipitate with the tissue anions (oxygen, chlorin, phosphoric acid, etc.) are caustic and local germicides of high quality when driven into tissue. These qualities are due to the facts that the union of these ions with the protoplasm of cell tissue of any kind causes death of the cell; the resulting compounds cannot be absorbed, or are absorbed with difficulty; and as a tissue irritant, some of them stimulate phagocytic activity leading to ultimate extrusion from the site of formation by a line of demarcation. An instance of a permanent or but slowly absorbable deposit of iron molecules from the ferric ion diffused from a steel needle anode into a wart has already been given. Leduc, in the work cited, relates an experiment in which the permanganate ion was driven into the skin of the arm of an assistant when a solution of potassium permanganate was placed under the cathode. The permanganate ion was immediately reduced by the tissues into an oxychlorid of manganese, shown by a brown, punctate rash starred over the surface, the process having been stopped early enough to show that the chief transit into the tissues was by the better conducting sweat glands, which produced the punctate appearance by being filled with the oxid of the metal. As this deposit is insoluble in the body fluids the marks were doubtless permanent unless removed by anaphoresis.

The local sterilizing ions most used are zinc, copper, mercury and silver. Iodin may be classed as both a sterilizing ion and one of medicinal value also, as it is readily absorbed further into the tissue at the end of the ionization.

General Surgical Uses of Sterilizing Ions.—The principle underlying the use of sterilizing ions in minor surgery is that the current is able to develop and disperse the sterilizing ions through any thickness of infected granulation tissue or other infected tissue in a focus of infection to the extreme limits of the deposit in an easily controllable manner, instead of the sterilizing agent acting only on the surface of the deposit as is the case with washes or other means of applying germicides. Sterilization may be *en masse* and at one application by this method if desired, but usually the applications are in less doses than sufficient to sterilize the cavity, if a cavity is under treatment, in order that the walls of the infected area may not also receive unnecessary ionization, the small doses received in the healthy walls in these partial sterilizations serving to arouse tissue resistance when it is needed in indolent ulcers. Such a course of progressive sterilization is suitable to all nonmalignant infected cavities and focal lesions, including tuberculosis, as described in Chapter X, but piecemeal sterilizations are to be avoided strictly in malignant growths as being too stimulating to the undestroyed portion.

These surgical ionizations of germ deposits and focal lesions are in effect electrochemical curettages, with the exceedingly important difference from mechanical curettage with a cutting instrument that in removing diseased tissue (the devitalized débris of which is spontaneously discharged from the cavity subsequently as a portion of the surgical procedure), *the absorbent vessels and lymph spaces in healthy surrounding tissue are not opened by the electrosurgical intervention but sealed by it,* the edges remaining sealed by the coagulant action of the ionization until this is replaced by the sealing effect of tissue repair. The result is that the possibility of accidental reimplantation of undestroyed or unremoved organisms is eliminated.

The author believes that ionic sterilization, as the most convenient method of accomplishing these purposes, points to a new and useful principle in the surgical treatment of purely local deposits of living bacterial or protozoal organisms, showing that they may be most safely destroyed *in situ* rather than removed

while living, with a risk in the latter case of reimplantation in the wound.

The technic of these various surgical sterilizations is that of the unipolar ionizations described in detail on pages 142 and 195, the active pole being the anode, whether it be of zinc, copper, mercury or silver. In a strictly surgical ionization, where we wish to destroy some tissue containing the organism, the author urges that the metal itself be used as the anode in direct contact with, or inserted by sharp points into, the diseased tissue. It is evident that some of the English and French workers in this particular field have erred in employing solutions of the ion (of 1 or 2 per cent. in water) for these surgical sterilizations, and with evidence in their reports of less success than has resulted on this side of the water in the treatment of tuberculous lesions of the skin for instance, because the solution did not permit of the boldness and accuracy that the directly applied ions from the soluble needle or probe of the metal would secure. Most of the following discussions refer to ions developed from metal anodes in direct contact with the lesion.

The zinc, copper or silver anode for sinus or abnormal cavity sterilization may be made from wires or strips of these metals shaped to enter the sinus, and when the mercury ion is desired it may be added to either of these metals by simply amalgamating (footnote, page 142) the probe with it, both ions then being diffused at the relative rates of speed and in the proportions indicated in the table at page 44.

The choice between the zinc ion, without mercury and with it; the copper ion, without mercury and with it; and the silver either alone or with mercury, all being developed from metal electrodes without covering or solutions, is somewhat definite; yet either may take the place of the others in an emergency.

The zinc ion alone is usually employed by the author with sharp pointed instruments to increase the dirigibility of the application, the employment of several points in solid growths permitting all parts to be treated simultaneously. It is particularly applicable to multiple puncture application when all diseased tissue is to be destroyed. The mercury is not needed to prevent the zinc sticking to tissues that are to be entirely destroyed, and has the disadvantage of making the points brittle and dull.

Zinc and mercury ions from amalgamated zinc anodes is the ideal application when the electrode is a dull pointed probe for

insertion into a cavity large enough to admit it, and demanding a maximum of destructive sterilization of disease deposits and indolent granulation tissue. It has the disadvantage at times of being brittle.

The copper ion alone is employed by many in situations in which less destruction and more sterilization is desired, the copper electrode, which tends to stick to the tissue after ionization, being removed after the current has been turned off, reversed and turned on again for a few moments as a cathode.

Copper and mercury ions from amalgamated copper probes or sounds are the author's preference for conditions where sterilization rather than destruction is desired. The speeds of these two ions are nearly the same, as shown in the table on page 44, though the table also shows that about three times as much mercury ions as of the copper ions by weight will be driven in by the same current strength.

The silver ion is but little used, as it is thought to be more easily reduced to metallic form in the tissues than the preceding ions. It is probably less caustic. When mercury is combined with it by amalgamating the silver surface about the same quantity of each is ionized, rendering it a less desirable surface from which to disperse mercury ions.

The pure mercury ion probably produces the greatest sterilization with least destruction of tissue. It is diffused from 18 karat gold electrodes by amalgamating the latter with quicksilver. In the first uses of such an electrode ions of the alloys in the gold will be diffused.

Conditions in Which Sterilizing Ions Would Seem to Be Indicated.—Reasoning from results obtained by the author in analogous conditions, minor applications of zinc-mercury ions would prove to be of value in the following conditions; chronic focal deposits of tuberculous matter in any situation capable of being safely reached by an amalgamated zinc probe; also the various granulomas when still localized and in accessible situations, particularly chancroid and a suppurating bubo; postoperative sinuses, etc.

Acute granulomas, such as the syphilitic chancre, might be aborted at once by a destruction of the initial lesion by a major bipolar electrothermic application of zinc ions, with the needles inserted thickly beneath and at some distance from the extreme edges of the primary infection, and a current of 500 to 1000 milliamperes, under general anesthesia. For appropriate technic

see page 195. In the case of syphilis, this would of course have to be done within five days of the first appearance of the chancre. The chance of cutting off the syphilitic or other serious infection would be worth the small effort involved in a fifteen-minute anesthesia with chloroform and the simple operative procedure; though doubtless, in the case of syphilis, but few patients could be seen in time to make the operation fully effective.

The Magnesium Ion (Diffused from the anode).—The magnesium ion, usually diffused from solutions of magnesium sulphate, occupies a middle position between the sterilizing ions and medicinal ions. So far as the author is aware it has been used only for the removal of thickly studded warts on the skin; but judging from the recent practice of employing solutions of Epsom salts as local applications to the surface of the body in various conditions, there may be a wider field for its usefulness.

A pad is saturated with a weak solution of the salt and placed as an anode over the warts surmounted by the conducting plate, and a moderate current turned on for twenty minutes. A number of observers in this country and in Europe report disappearances of the warts after one or more such applications, several days or weeks being needed for the exfoliation by attrition of the dead cuticle, and the author has recently obtained a similar result in the case of general verrucosis on the hand of a young girl. All of the warts gradually disappeared after the third application.

MEDICINAL IONS

Medicinal ions are those ions which, when diffused into a part of the body by electric power, form noncauterant molecules in the tissues and fluids by union with opposite body ions, molecules which do not differ in action from the same chemical substances inserted into it in any other way, except that, when driven in as ions, *they have been driven into immediate union with intracellular substances* near by as well as into the fluids; that they can be made a part of the circulation and tissues in a portion of the body without a general administration of the remedy; and that they remain in the local tissues longer than when administered differently, indicated by slower elimination.

Technic of Medicinal Ionizations.—All medicinal ions are driven in from solutions of 1 to 5 per cent. of their salts, preferably dissolved in distilled water and used as a local bath surrounding the part, if an extremity, the bath being put into

circuit by a plate electrode of carbon or aluminum. The bath container should be of glass, porcelain, wood or enameled metal, and another receptacle with salt water and conducting plate should be provided for the opposite extremity in completion of the circuit.

If immersion in a local bath is impracticable, a thick pad of absorbent cotton is saturated with the solution and placed on the desired spot (which has been cleansed of oily matter by soap and water or gasoline) and on top of the pad a carbon, block tin or thin aluminum plate of much smaller size is placed, care being observed that an equal thickness of the pad is interposed between the plate and skin at all points. All breaks in the skin surface, such as scratches, pimples or red spots must previously have been covered with a bit of vaseline and paper or with collodion. Should the patient feel unusual burning sensations at any spot the treatment should be interrupted and the spot covered, else most of the current will pass through the weak portion of the cuticle and create irritation. Large ionization pads may be held in place by bandaging or by sand bags. The indifferent pad should be larger than the active one and placed on the opposite side of a limb or on some distant part of the body.

The most perfect electrode pad for medicinal ionization is made for each patient from kaolin and gauze as follows, the electrode being kept in a glass, porcelain or enameled ware dish of proper size and shape, labeled with the patient's name and set aside between treatments. Cut a piece of gauze of a size that when folded three times it will be about three times the width of the desired pad. Spread it over the pan and place sufficient dry kaolin powder in the middle to make a pad of proper shape and about three-quarters of an inch thick. Pour over this the warmed solution of the salt until it is thoroughly saturated; fold the remaining portions of gauze over the top and transfer the pad to the skin surface. Such a pad will adhere of itself to the skin surface, and will make such perfect contact as to be least liable to cause skin lesions if they are not already present. The circuit is completed with a thin aluminum plate.

At the completion of the treatment the pad is transferred to its labeled pan and kept for the next application to this patient. When used again it is moistened with hot water with a little of the solution added.

This electrode is economical in first cost and particularly

saving in waste of the material used for ionization, as what is left in the pad may be used again, it being unnecessary to employ solutions of exact percentage. The same amount will be diffused from any solution over about 2 per cent. If evaporation makes the solution in the pad stronger, no fresh ions should be added to the water used to make up for evaporation.

Electrode baths for the limbs of the body present an excellent method for introducing ions into the extremities. These are best made by filling two graniteware or porcelain foot tubs with a solution appropriate to the ion to be diffused, and connecting them up by a conducting plate in each tub.

Sclerolysis with the Chlorin Ion (diffused from cathode).—On account of the frequent use of this method of quickening the absorption of sclerosed tissue by the chlorin ion in the reconstruction hospitals of late, and of its possible usefulness in industrial surgery, I have thought it well to quote Professor Leduc's own words on the subject:

"One of the most constant actions of ionization is the resolving influence on sclerous and cicatricial formations of a cathodal stream from a solution of chlorid of sodium. Joints completely anchylosed recover their mobility rapidly without forced movements or pain. The anchylosis disappears progressively from day to day, and the joints regain all their mobility. It is now more than fifteen years since we pointed out these effects, and indicated the conditions necessary to obtain them. Since that time our appreciation of the value of this treatment has continued to increase. The resolving action of the chlorin ion is not a matter of chance. It is regular and sure. No other means employed in medicine can be compared with it for efficacy, rapidity, perfection of results, and absence of pain. To apply the treatment we employ a 1 to 2 per cent. solution of chlorid of sodium. The indifferent electrode, the anode, may consist of a local bath for the feet or arms. Frequently we employ a large compress of absorbent cotton-wool folded in sixteen thicknesses impregnated with a warm solution of sodium chlorid for the anode, which is wrapped around one leg. It is covered with a sheet of tin, which is connected to the anode.

"The whole is kept in place by a few turns of a bandage. The active electrode, the cathode, is made up in the same way by a bath of salt water, in which the affected region—e.g., the hand, is immersed, or may be by a compress of sixteen thicknesses of absorbent cotton-wool saturated and wrapped around or applied to the affected part—e.g., the knee. It is of advantage to make several turns round the limb, so that there are thirty-two or forty-eight thicknesses of tissue between the skin and the plate of tin connected with the negative pole. This arrangement gives a good surface contact to the electrolyte, and protects against the caustic action of the ions produced at the point of contact of the metal plate. The electrodes are then fixed by suitable rheophores to the terminals of the generator, whether this be cells, accumulator, or a reducer of potential in series with a continuous current, a cell collector, a simple reducer of potential, or a rheostat whose resistance one gradually diminishes. The strength of the current is gently but progressively increased, as indicated by the milliamperemeter inserted in the circuit. The pain produced is not in proportion to the strength of the current. It depends rather on the speed with which the current is increased. It diminishes or disappears when the strength of the current has reached its maximum and remains constant. At first the patient will complain of a current less than 10 milliamperes, but after a quarter of an hour he will tolerate 100 milliamperes without any pain. This depends on the fact that at the commencement of the séance the strength of the current rises rapidly and spontaneously owing to the diminution of the resistance. It is therefore very important to increase the strength of the current very gradually, and to take the patient's sensitiveness into consideration. In these applications the limit of strength of the current is only marked by the limit of the patient's tolerance. If the applications are carefully made, there is no fear of accidents or burns. With solutions of chlorid of sodium, burns are produced only if there is any wound of the skin, e. g., some excoriation or pimple which constitutes an orifice, through which the current rushes and acquires a density which gives the patient a severe burn.

"As soon as the patient complains of such localized pain the current should be gradually diminished, the electrode should be removed, and the excoriation should be sought for and wiped with a tampon of absorbent cotton soaked in alcohol. It should then be covered with a drop of flexible collodion, which, after drying, does not allow the current to pass, and the séance may be continued. To obtain rapid results the séances should be prolonged—not less than half an hour in duration with the maximum current. Applications should not be more than three weekly, as the skin and the tissues remain affected for a very long time by each application. The resistance to the destructive action of the current (on the skin) and the tolerance diminish from one séance to another. If the treatment is prolonged, it is necessary to increase the interval between the séances, giving at first two and then one per week. Success is only certain if the morbid agent has ceased to act and no infectious agent

intervenes to counteract the effect of the treatment. The rapidity of the result and the degree of efficacy depend essentially on the site of the sclerosis. If the fibrous tissue is immediately under the skin, as in the hands or feet, it is easily accessible to the current, whose action is then rapid and complete. On the other hand, in the hip-joint and the shoulder the sclerosed tissues are surrounded by masses of muscle which are very good conductors, and form a screen which deflects the current and allows only a small part of it to penetrate to the diseased tissues. In these regions the results are slow and incomplete. Progress is always most rapid at the beginning of the treatment, because superficial tissues are the first to be strongly influenced, while the action on deep structures is more feeble and slow.

"We have often made use of this sclerolytic property of the electric current, and we can foretell its results beforehand. Among the cases treated we may instance a complete anchylosis of the fingers, following an abscess in the hand, in a young soldier who was treated in a military hospital for six months by different methods, among which was forcible movement under chloroform. As there was no improvement he was dismissed from the army. After two séances with his hand in a bath of a solution of chlorid of sodium, which took the place of the cathode, for a period of thirty minutes with a current of 30 milliamperes, he recovered the power of movement so completely that no trace of anchylosis remained. A state forester, after six months of immobilization for a phlegmonous arthritis, had his knee completely anchylosed for five months. After two months' treatment, consisting of nine sclerolytic séances, each of which lasted forty minutes, with a cathodic compress impregnated with sodium chlorid and a current of 100 milliamperes, he could walk perfectly. He was able to resume his duties, which he has continued without interruption ever since. The treatment began with two séances per week, and then one every fortnight. A young woman had an anchylosed knee-joint after typhoid fever. It was a very painful variety of chronic arthritis, which had remained unaltered for eighteen months. After twelve electric séances, with a cathode applied to the knee, the pain disappeared, as well as all the thickening of the tissues, and the movements became free.

"The indications for sclerolytic treatment are frequent, and we have had many cases, in all of which the results have agreed with the instances quoted. This electrical sclerolytic treatment is applicable not only to the limbs, but to all parts of the body accessible to the current. It has given us very remarkable results in the treatment of rheumatic scleritis and periscleritis. We have cured a number of old cases which had been

treated without success by salicylates and iodid of potassium in various ophthalmological clinics. The anode is applied to any suitable part of the body, and a tampon electrode covered with several thicknesses of absorbent lint impregnated with a warm solution of sodium chlorid is applied and kept for a quarter of an hour on the upper eyelid. The eye being shut, the strength of the current is gradually raised to 5 or 6 milliamperes, and two or three séances are given weekly. The pain rapidly subsides, the granulations and the vascularization of the sclerotic disappear, and complete recovery rapidly ensues. We have had no failures, and we have treated very old cases which had traveled round the ophthalmic clinics of France and other countries for some years. This treatment gives good results also in cases of chronic iritis with adhesions." [1]

The Lithium Ion (driven in from anode).—Thomas A. Edison [2] in some experiments conducted under medical supervision pointed out that lithium may be detected in the urine when driven into a gouty hand dipped into a 5 per cent. solution of lithium chlorid with the other hand in a solution of common salt. A prolonged course of these treatments ameliorated the condition.

Guilloz [3] has used currents up to 200 milliamperes, the anode plate being placed in the lithium bath with the affected member, and the cathode, a large pad, on the back or in a second bath. A number of other writers have also reported good results, the best results having been obtained in the cases in which the diagnosis of gout was most clearly established.

Uric acid may be withdrawn from a gouty joint by the same electrode that drives in the lithium if powerful currents are used for prolonged treatment, the acid being drawn into the lithium pad or bath instead of the body anions that appear at the anode. This was demonstrated during the treatment of a case by Bordier [4] in which he used the same 2 per cent. solution of chlorid of lithium for several days in succession. The liquid in the bath eventually deposited a sediment. This was collected, and on analysis was found to contain uric acid. The patient was much improved by the applications, and at the end of a month

[1] "Electric Ions in Medicine," p. 44.
[2] See Peterson's article on "Cataphoresis" in "International System of Electrotherapeutics," Bigelow and Massey, F. A. Davis Co., Philadelphia, 1904.
[3] Cited by Lewis Jones, p. 87.
[4] *Archives d'Electricité Médicale*, 1910, p. 531.

the swellings had diminished and the tophi had become softened. Eighty milliampere currents were used for a half hour daily.

The following interesting discussion of lithium ionization is taken from Lewis Jones:

"Owing to the small combining weight of lithium, the amount conveyed into the body at an ordinary application is small. For instance, with 25 milliamperes for an hour the amount of lithium set in movement is only 5 milligrammes, and if the amount actually penetrating is half of this, the quantity appears very little; but, on the other hand, the quantity is sufficient to convert 50 milligrammes of uric acid into soluble lithium urate, as has been pointed out by Labatut, who also compares the local effect of lithium introduced by ionization with that of lithium given by the mouth. He says that if half a gramme of lithium carbonate be given by the mouth, and is all absorbed, the amount of actual lithium distributed through the body is 5 milligrammes, and that it is quickly eliminated by the kidneys; while if 5 milligrammes is introduced locally by ionization, the concentration of lithium around the point of introduction is ten times as great as after administration of the former dose by the mouth, and that it remains longer in the tissues, and cannot be detected in the urine until after the lapse of forty-eight hours.

"A point of interest depending on the small atomic weight of lithium (see page 44), is that 1 ounce of lithium chlorid contains only about 80 grains of lithium, and 1 ounce of lithium citrate about 40 grains of the metal. A 3 per cent. solution of the chlorid would contain 2 grains of lithium to the ounce, and 3 or 2 per cent. solutions should be preferred to the strength of 1 per cent. usual for ionic applications.

"Lithium may be diffused from the anode while the ions of iodin or salicylic acid are driven in from the cathode, and in this way the simultaneous employment of two drugs useful in gout can be combined." [1]

The Salicylic Ion (diffused from the cathode).—Leduc, Lewis Jones and others have made extensive use of the salicylic ion, both for its local antiseptic action on inflamed wounds and sores, including acne, and for the relief by deeper diffusion of rheumatic conditions and neuritis. As it is an anion, the plate covering the thick pad may be of the thinnest tin and lead alloy, permitting accurate apposition to curved and irregular surfaces. The pad itself should be thick.

The salicylic ion is so well tolerated by the skin that large

[1] "Ionic Medication," p. 88.

doses may be used without discomfort to the patient. Solutions of 1 and 2 per cent. are generally used; and as salicylate of sodium is a very soluble salt, it can be kept in strong stock solution and diluted for use with very hot water, as it seems to act more favorably when used warm.

The Quinin Ion (diffused from the anode).—This ion has been used with success in a number of cases of trigeminal neuralgia and other neuralgic conditions for which the salicylic ion is also much used. It has been employed in herpes zoster successfully. The hydrochlorate is a better salt to use than the sulphate as it dissolves in water readily (1 part in 40), without the use of acid. As the quinin ion is a cation we must select the least attackable metal for conducting plate, such as thin aluminum, or else apply very thick pads of absorbent cotten when tin alloy is employed and reject the pad after treatment to get rid of any lead ions that may be in it.

The Iodin Ion (diffused from the cathode).—The remarkable penetrating qualities of iodin when simply applied to the skin or mucous membrane in alcoholic solution indicate the possibilities of its use when this penetration is greatly increased by electric power. Its possible value in accentuating internal administration of the same ion in the treatment of gummas near the surface, and of many other conditions is manifest. Unfortunately, some have found it too irritating to the skin. We believe that this has been because too strong a solution has been used.

A solution of sodium iodid of a strength of 1 to 2 per cent. is sufficient.

CHAPTER VI

THE PHYSICS OF HEAT PRODUCTION WITHIN LIVING TISSUES BY ELECTRIC POWER

Externally Developed Electric Heat—The Hot Wire Cautery—Radiant Heat—Heat Developed by Current Conduction Within the Body Tissues—Relation of Diathermic Heat to Breadth of Skin Conductors.

It has been seen in Chapter II that the flow of electrons in a conductor, from molecule to molecule if a metal and by ionic flow if an electrolyte, is opposed by the inertia of the conductor, an opposition to the flow of electrons known as resistance. We have considered resistance as an obstacle to flow only. It is now necessary to consider resistance to flow of electric power as a means of transforming the power into heat.

The correlation of the physical forces, now so well understood, teaches that one form of force may be transformed into another by adequate effort and at the cost of necessary losses, the losses being a by-product, as it were, of the transformation, and containing within themselves the balance of the energy originally used, plus that in the main product. Thus nothing is actually lost. Heat is an invariable by-product of electric resistance, though often so slight as to be inappreciable. All transfers of electric energy in wires, electrolytic solutions and living tissues *raise the temperature of the conductor in direct proportion to the resistance encountered and the amperage of the current.* Very great amperages are necessary to raise the temperature of a copper wire of ordinary size, hence we do not detect temperature changes in such wires with our ordinary currents, but as soon as the wire is made sufficiently fine in caliber an appreciable rise is evident. The hot wire meter for measuring alternating currents makes use of this principle.

If we insert in a circuit of copper wire connecting the terminals of a low pressure, high amperage source of current a piece of platinum wire of the same caliber, the resistance encountered by the current while passing through the platinum part of the circuit will be about seven times as great as that in the

copper, that being its specific resistance compared with copper, and we will have a temperature about seven times greater in the platinum section of the circuit than in the copper section. The increase will be even greater if the platinum section is smaller in caliber than the copper. This is the principle under which the platinum hot wire cautery produces heat, transformed most conveniently from an alternating current of 4 volts (greater voltage not being required for an all-metal circuit) and a volume of from 20 to 100 amperes. On account of the high cost of platinum, nickel may be substituted for it, but larger amperages will be required.

A given amperage will produce heat in a conductor in proportion to the resistance encountered, whether the resistance be specific to the special molecules of the substance of the conductor or be due to its narrowness. A given conductor of fixed specific resistance and definite width will, correlatively, increase in heat step by step with increased amperages of the power traversing it.

These laws of electrokinetics give us not only these clues to the use of the heat by-product of current resistance as a chief product in heating a wire for surgical purposes, but also for heating the body tissue conductor itself by the passage of sufficient amperages through it. The difference between the two methods of applying electric heat in surgery—that externally developed in a hot wire, and that internally developed by the electric current in the body tissues themselves—is so great that separate consideration is necessary.

EXTERNALLY DEVELOPED ELECTROSURGICAL HEAT

The Hot Wire Cautery.—This is a device for the use of electric power as a convenient source of cauterant heat at a given small spot. When the spot to be cauterized is in a cavity, it enables us to place the instrument in position while cold and then turn on the heat to any degree desired.

By utilizing the principles of induction we may readily transform the 110 volt street alternating current into an alternating current of 4 volts and very large amperage without drawing a heavy amperage from the lamp socket. This is known as a "step-down" transformer, and is so effective that when direct current supply alone is available, a motor-generator is used to turn the direct current into alternating for this purpose.

The A. C. step-down transformer for cautery knives, Fig. 24, consists of a long, fine wire primary coil of many turns through which the current from the mains circulates, covered by a short, thick wire of few turns, being thus the reverse of the faradic coil. The knife loup is in circuit with the coarse wire secondary, which absorbs current by induction as each turn slides over the primary, or is otherwise exposed to the primary.

The Downes transformer for the alternating current, shown in the cut, is very efficient, giving a current of 4 volts and a

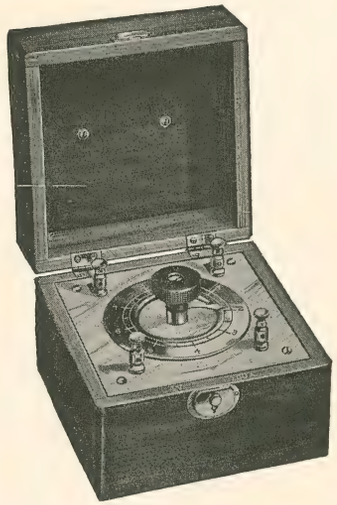


Fig. 24.—Downes Alternating Current Transformer for Cautery Knife. An assistant turns the handle of the transformer controlling the heat, as contact with the tissue chills the hot knife, leaving the surgeon free to handle the latter.

maximum of 100 amperes. The knives and cautery spiral (Fig. 25) are also well adapted to the operating room, being free from complexities and capable of complete asepsis by boiling, while the conducting cable is also aseptic and capable of carrying the current load.

In employing this instrument, tests of the heat-bearing qualities of a given knife should be made cautiously, before the operation, to test the point of the indicator where the desired heat is attained, for one is liable to fuse the loop with too much current, particularly the smaller ones. When the knife is in

contact with the moist tissues, nevertheless, more heat will be needed than in the air, due to convection of heat from the loop. A foot switch is a convenience to the surgeon, for the spring switch in the handle is sometimes awkward. The Downes direct current cautery transformer (Fig. 26), contains a motor-gen-

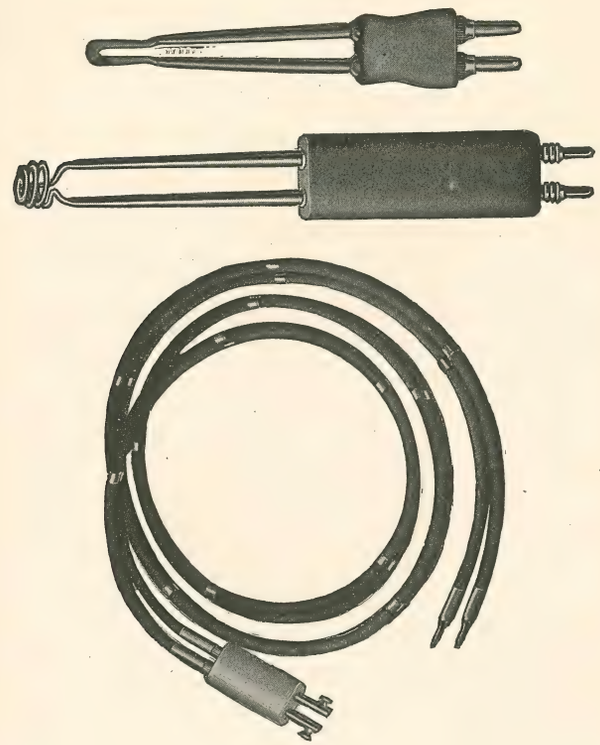


Fig. 25.—Heavy Cautery Knife and Button, and the Asepticizable Conducting Cable of the Downes Cautery. The cautery loop, in this instrument, is made of nickel, and is more rigid than those made of platinum. The fact that more current is required than will heat a platinum wire is negligible when a transformer supplies it. Cautery knives for use within the nasal cavity are preferably made of platinum.

erator, in which the direct current motor drives an A. C. dynamo producing a current similar to that of the A. C. cautery transformer described.

Radiotherm Hot Knife.—Wappler has recently placed on the market a high frequency generator in which radio tubes replace

the spark gap. (See page 95.) This produces a current that is specially adapted to bloodless cutting operations, the cut surface being perfectly sealed as it is made, yet the thermic destruction of the cut surface, when a sharp knife is used, is so slight that union of the cut surfaces may occur.

Radiant Heat.—Electric light baths, whether by means of an individual 50 watt reading lamp with parabolic reflector

FIG. 26.—The Downes D. C. Cautery Transformer.

placed over a painful area in which we wish to produce hyperemia, or by local or general electric light bath apparatus, offer a most valuable mode of radiating heat and light into the body, that probably differs somewhat from conduction heat from ordinary sources, and is a valuable therapeutic agency in both acute and chronic disease. As this work is more concerned with surgical measures, interested readers are referred to special treatises on the subject.

HEAT DEVELOPED BY CURRENT CONDUCTION WITHIN THE BODY TISSUES

With the living tissues as a conductor of electric power we have exactly the same laws of heat transformation in a conductor as stated above for metallic conductors. This indicates that in a broad conductor, such as a portion of the body included in the circuit between two broad metal plates on the surface, the path of the current is so wide and the resistance of the soft tissues so moderate, that large currents must be employed to raise the tissues to a therapeutic heat value throughout the circuit. Such heating currents for medical use must therefore be of the high frequency type (Chapter VIII) to eliminate both chemical action and wave action, though a direct current of equal amperage may be employed in electrocoagulation with the direct current when confined to the tissues to be destroyed, as in the bipolar electrocoagulation of malignant growths.

The heat production features of the high frequency current have only recently been recognized as a means of raising the temperature of deeply seated organs for medical treatment. Their value is based on the interesting fact that the heat is produced equally throughout the circuit, being nearly as great in the center of the path between two electrode plates on opposite surfaces of the body as beneath the plates themselves. That it is slightly greater within the skin structures beneath each plate than in the moister tissues deeper down is due only to the greater resistance presented by the skin. This is a clinical advantage in practice so long as the skin is not anesthetic, as the patient's sensations are a valuable assistant to the meter reading in guiding dosage.

This fact of heat production being directly proportional to resistance encountered (whether due to a narrow path, or, as more frequently encountered in medical diathermy, due to greater dryness or greater density of portions of the path between the two plates), will give us the key to the behavior of medical diathermy currents in tissues beneath the skin. If compelled to traverse bone, for instance, without adequate path for these high velocity currents around it, greater heat will appear in bone than the soft parts. Nerve trunks are probably heated slightly more than muscle tissue, with the same density of current.

Heat production in a high frequency circuit traversing the

intestines must be greater in the intestinal walls than in overlying muscular tissue. The same is true of lung tissue (except when the latter is consolidated, as in the early stages of pneumonia), for the air spaces in either case are practical nonconductors when inflated, the current passing through the membranous tissue alone.

Relation of Diathermic Heat to Breadth of Skin Conductor.—The path of a high frequency current through the tissues after traversing the skin or mucous membrane is considered more fully in Chapter VIII. But it is important to consider in this place the relation of the epidermic port of entry of the current to its path deeper down. The broader the path of any power the less the resistance, and in this case, of course, the less the heat produced by a definite amperage. One thousand milliamperes of high frequency current passing through the body between electrode surfaces of 4 square inches each would produce far less rise of temperature in the path than if it were confined to surfaces of but 2 square inches. To heat the 4 inch path to the same temperature as the 2 inch path would require that the current be doubled.

These facts indicate that deep medical diathermy requires heavy milliamperages because of the breadth of the deep path that includes the organ, the external electrodes being also necessarily large enough to carry the current through the skin without discomfort.

The physics governing the concentration of electronic heat for electrocoagulation are naturally the converse of the laws cited above. Here we produce a destructive heat within tissue by either narrowing the port of entry, and consequently the path of the electrons through the tissue to be destroyed, thus increasing the heat from a given current; or, with as narrow a port of entry that will remain moist enough to continue as a conductor, we increase the milliamperage to produce the desired effect.

CHAPTER VII

WAVE CURRENTS

Wave Action of Electric Currents—Cause of Wave Effect on Neuron and Muscle; Polarization and Depolarization—Wave Effect Essential to Muscle Stimulation—Importance of Shape of Wave—Direct Current Waves—The Alternating Current Supplied for House Lighting—Special Action of Alternate Waves—The Question of Wave Frequency; Essential Difference between Low Frequency Currents and High Frequency Currents—Rhythmic Currents—Rhythmic Galvanic Sinusoidal Current—Rhythmic Surges of Nongalvanic Currents—Static Wave Currents.

Wave Action of Electric Currents.—We have heretofore considered chiefly the application to living tissue of a continuous stream of electrons. There is another quality of stream action of an electrical current that is important, for it permits us to play upon and stimulate the physiologic functions of body organs. This is the blow-like action of a wave of sudden rise or fall of potential of a current traversing a part. This action differs from the continuous current action somewhat as the differences between the force of a steady stream of water, with power due to pressure and volume alone, and that of water waves, *which strike an object with a momentum made up also of pressure and volume, but with the added effect of impetus or suddenness.*

Cause of Wave Effect on Neuron and Muscle; Polarization and Depolarization.—If, in a state of quiescence, the molecules of a living structure, pursuing the equable ionic changes incident to metabolism and tone maintenance, are suddenly thrown into another tactical formation by a foreign electric current with a flood-crest wave, an immediate rearrangement of the ions of the part is precipitated, more or less violent in proportion to the current volume of the wave and the sharpness of its crest. The structure becomes polarized by electrochemical adjustment to the polarity at each pole, producing chemical changes that store

up energy, as in the storage cell, to be released by a sudden dissipation on stoppage of the current. Such productions of polarization and depolarization, when applied to the protoplasm of a nerve or muscle in a sudden wave, stimulate the part to a functional response.

Wave Effect Essential to Functional Stimulation of Nerve or Muscle.—Moderate ionic change slowly applied to a neuron or muscle fiber produces ionic readjustment so gradually that there is no artificial excitation of the function of the nerve or muscle fiber; but if the same ionic change be suddenly created in the organ by a foreign current wave the forcible ionic orientation acts as a stimulus to the functioning or conducting substance and the end organ will respond as if it had received a centric impulse, though "cut in" along the line in reality. A sudden ionic change in a conductor or producer of function is not the only artificial means of "cutting in" an excitation. A blow on a sensory nerve, particularly the ulnar nerve at the elbow, will give results familiar to all, while the contraction response of a bundle of muscle fibers to a blow with the point of a rubber hammer is familiar to neurologists.

That secretory organs can be similarly stimulated to function by an excitation "cut in" along their lines of communication is demonstrated by the results of direct current wave stimulation of the salivary gland; while the electric flash, taste and sound responses are known to be direct neuraxon stimulations at times, though at other times they may be the reflex effect of stimulation of other efferent neurons.

The electric stimulation of special physiologic functions by currents of ordinary strength requires, therefore, a more or less sudden variation or wave of the ionic state of the organ, the amount of the stimulation bearing a direct relation to the volume and extent of the variation and to its time element. The time occupied in the variation is important and of much practical application in the selection and application of rhythmic wave currents to various parts of the body, as will be pointed out later.

The relation of most of these factors to the amplitude of the contraction of motor nerves and striated muscle was long ago pointed out by the pioneer student of electric phenomena in living tissues, duBois Reymond, who formulated a law as follows: The absolute volume of the current at a given moment does not act as a stimulant to the motor nerves, but merely the

change in its amount from one moment to another, i.e., only the variations in its volume; these act so much the more powerfully the greater they are in the unit of time, or, their amount being equal, the more rapidly they occur; most powerfully, therefore, upon sudden closure and opening of the current.

Weiss, an Italian research worker, has recently shown that this law should be modified in the time factor to suit the differing time elements in the function-response of organs. An organ that is naturally or pathologically sluggish in its response may not respond at all to a stimulus that is too brief, no matter how high the voltage of the change.[1]

Importance of Shape of Wave.—Graphic records of current waves may be recorded by proper apparatus on revolving cylin-

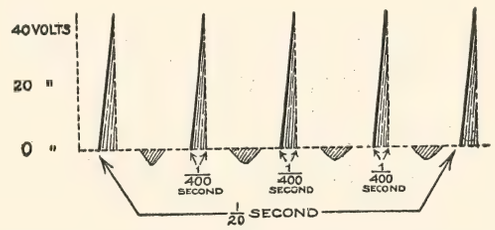


FIG. 27.—Diagram of Faradic Waves. Only those above the neutral line of no current are physiologically effective.

ders, which are accurate except when the waves are exceedingly brief, as are the faradic waves formerly employed in medicine, whose duration has been found to be but one four-hundredth of a second or thereabouts. These records verify duBois Reymond's law, as modified by Weiss, and moreover show us that there is an important relation between the smoothness of the slant of the wave and the painfulness of the response as well as its amplitude. The faradic wave, for instance (Fig. 27), made up of a cycle of one cathodic wave and one anodic wave (the cathodic wave being the only one of physiologic or therapeutic importance because of magnetic "reluctance"), is so sharp and of such brief duration that, though it acts well on healthy voluntary muscles and motor nerves, it fails to stimulate the muscle the subject of Wallerian degeneration, or, according to Guilleminot, the unstriated muscles of the intestines, when applied percutaneously. Another reason for the rejection of the faradic cur-

[1] Guilleminot, "Electricity in Medicine," 1906, p. 239.

rent for therapeutic work in favor of those waves to be described below is their extreme irregularity, with resulting painfulness and reduced motor response due to interference between contiguous wave actions. This irregularity of the faradic wave is due to the mechanical features of the current-break mechanism, which have never been capable of adequate correction.

Direct Current Waves.—If the direct current be turned on and off abruptly, as was done forty years ago with the currents of unknown volume from acid batteries (when the patient permitted it), the response of all kinds of nerves and muscles is

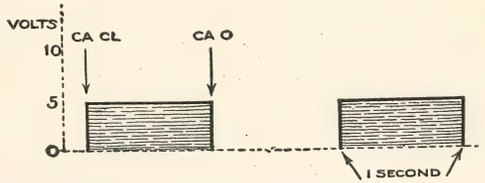


FIG. 28.—Diagram of Abrupt and Painful Galvanic Waves.

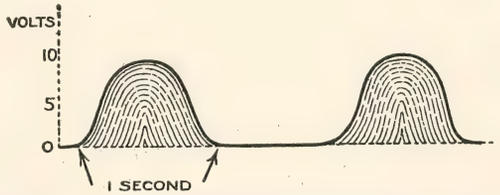


FIG. 29.—Diagram of Less Painful Galvanic Undulatory Wave or Surge.

ample and thorough, but the painfulness of such waves bars them from therapeutics of any kind. The abrupt rise and fall of these waves is shown in Fig. 28. But if the direct current be turned on and off gradually in smooth curves (Fig. 29), we will have an undulatory wave that is much less painful, though still giving rise to a burning sensation due to the fact that the wave is all above the zero line and therefore possesses the full ionization action that goes with its volume and duration.

The method by which the direct current may be comfortably applied in the rhythmic surges now considered essential in wave current therapy will be found on page 75. These rhythmic surges have as their basal currents either the direct current in alternate

waves, the alternating current of the mains, alternating waves generated in special apparatus, or the unidirectional static current. The direct current having been described in preceding pages, the other currents capable of being applied in rhythmic surges will be described before taking up the subject of the surges themselves.

The Alternating Current Supplied for House Lighting.—Alternating currents, which are generated by apparatus which we will not occupy space in these pages to describe, are current impulses produced by induction in moving coils of wire rotating alternately before the north and south poles of electromagnets in an alternating current dynamo. The brief waves thus produced are alternately cathodic and anodic in direction, and have a pressure and volume determined by the size and type of the dynamo. The waves are smooth and sinusoidal in shape, and

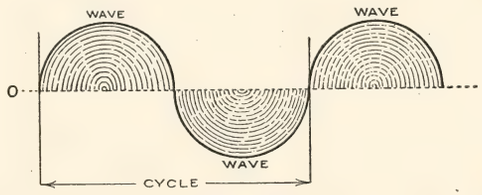


FIG. 30.—Diagram of a Single Phase Alternating Current. The cycle has one cathodic wave and one anodic wave.

therefore permit a maximum of motor excitation with a minimum of sensory discomfort. As received at the lamp socket the commercial A. C. has a pressure of about 110 volts and a volume limited by the size of the fuse inserted between the mains and the lamp socket.

As manufactured, the commercial A. C. is stepped up to 66,000 volts at the power house for long distance transmission, this high voltage current being retransformed to the low voltage of house supply by transformers on the line near points of distribution.

The A. C. thus supplied to the lamp socket is usually of single phase, 60 cycle type, with a voltage of about 110 volts.

By 60 cycles is meant that number of cycles *per second,* as cycles are rated by electrical engineers in seconds, the cycle being a complete turn of an armature wire before both north and south poles, producing the cathodic and anodic waves in sequence (Fig. 30). There being thus two waves per cycle would give 120

waves per second or 7,200 waves per minute. Waves are rated in minutes.

By single phase is meant a plain sinusoidal current made up of a cycle with but two waves, one above and one below the zero line of no current as shown in Fig. 30. A two phase cycle is one in which another phase follows the first at a slightly

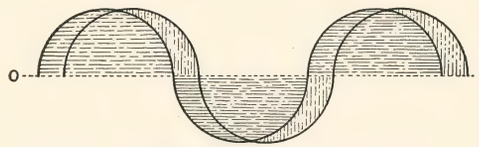


Fig. 31.—Diagram of Two Phase Cycle.

retarded time. The result in waves is shown in Fig. 31 in different shadings, the double waves rendering this particular current unavailable for use as such in medicine because of the interference of one wave with another, while it is better for power uses as it gives a steadier pull on the motor.

When power may be used in the house to any great extent

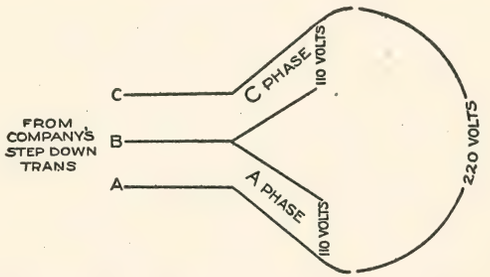


Fig. 32.—Diagram of Three Wire House Supply of Alternating Current. A and B wires, or B and C wires give 110 volts, while 220 volts may be obtained from A and C wires.

it is supplied with three wires from the nearby transformer giving both phases, A phase and C phase (Fig. 32), or but two wires may be supplied, giving but one phase. With the three wires, a house may have a portion of its supply from each phase with economy of wiring, but in either case each lamp socket is supplied with a single phase current of 110 volts and 72,000 waves per minute.

Special Action of Alternate Waves.—D'Arsonval was the

first to call attention to the value of a sinuous form of alternate waves as a means of obtaining a maximum motor response with a minimum of sensory discomfort. These waves derive their advantages in certain applications not only from their smoothness and the fact that ionization and electrolysis are instantly negatived by reciprocal reversals when not desired, but to the fact that the nerve and muscle stimulus of a given pressure and volume is doubled by the immediately following opposite wave of equal pressure and volume. Tissue polarity simply raised and allowed to fall to zero, as in the nonalternating wave or undulation (Fig. 29), falls to a double extent when it not only falls to zero but to an equal distance beyond it. This is illustrated by the diagram, Fig. 33, which shows that, in an analogous way, one can fall twenty feet from a staircase landing that is only ten feet above the street level if one falls at the same time

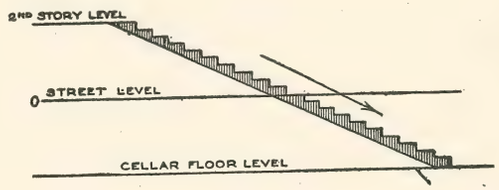


Fig. 33.—Diagram Showing that, if the Street Level be Considered Zero, and there are two floors, each ten feet above and below it, one may fall twenty feet from a ten foot second story level.

another ten feet down the cellar stairs. A difference of potential equal to that between the top of the cathodic wave and the bottom of the anodic one, when above the line, would produce less response in function and be attended by electrolysis.

The Question of Wave Frequency. Essential Differences Between Low Frequency Currents and High Frequency Currents.—In preceding paragraphs on wave stimulation it was pointed out that a wave of increase or decrease of power was essential to arouse function. The duration of such a stimulus has a twofold importance: first, the polarization action requires time for ionic change; while, second, the stimulated part requires an even longer time to rise into an impulse of function. Similar considerations govern the intervals between waves, requiring, first, sufficient time for electrical depolarization or fall to equilibrium, and, second, an even longer time for subsidence of the vital stimulus produced by the wave. If, therefore, waves

are too close together there will be, with increasing frequency, first an interference with response, lessening its amplitude, and later, with lessening intervals (or increasing frequency), an entire absence of manifest tissue response in the way of aroused sensory or motor functions.

During such an increase of wave frequency from single waves to those that may be called of low frequency, there is first a blending of responses at about 2,400 per minute into an apparently single muscular response, for instance, called tetany, though the sensory nerves still distinguish separate waves. From 2,400 per minute to about 50,000 per minute there is increasing smoothness of the muscular tetany in voluntary muscle and lessened sensory response. Beyond the latter figure both responses lessen until at 500,000 *per minute* they cease entirely.

To produce similar stimulation of *unstriped* muscle a much lower frequency is required.

Beyond half a million waves *per minute* a current ceases to be of low frequency, yet the true high frequency current effects are not attained until the frequencies reach millions *per second.*

Low frequency wave currents and high frequency currents are therefore *entirely different therapeutic agents and far apart in their effects.* They have only been grouped here in allusion because both are alternating and not direct, and possess therefore no permanent electrolytic or ionizing action. For further clearness it should be added that the labels "high," "medium" and "low frequency" found on high frequency apparatus have no reference to the low frequencies mentioned here, merely distinguishing between a possible ten or more millions *per second* at "high" and one or two millions per second at "low."

RHYTHMIC CURRENTS

There has been so much confusion in the minds of physicians as to the nature and clinical indications of the various wave currents classed together as "sinusoidal" that a clear separation and more definite labeling of these currents are greatly needed. To do this it will be necessary to insist that there are two characteristics of the wave currents of variable power heretofore grouped together as sinusoidal.

One characteristic is that the wave shall be a complete cycle of reversal of polarity produced by a mechanism that does this smoothly, with a sine curve. All alternating currents smoothly

produced and of single cycle are therefore sinusoidal currents, in spite of the fact that if they are not further made to surge in strong surges composed of many of these rapid sinusoidal waves they will produce tetanic contractions and not rhythmic contractions. A galvanic current from any source passed through a machine for an alternate turn on—turn off—and similar smooth turn on of waves of opposite polarity in regular sequence becomes also a sinusoidal current, and at the same time a rhythmic current of the greatest value if the waves are slow enough for the physiologic responses referred to below.

The other characteristic, found only in currents labeled at present "slow sinusoidal" on the labels of these machines, but which it is hoped manufacturers will properly label in the future "rhythmic galvanic" and "rhythmic nongalvanic" currents, is that, whatever form of current be supplied in rhythmic surges, be it rapid sinusoidal waves or the direct current in a sinusoidal wave, that *these should surge in rhythmic unison with the natural muscle movements of the part of the body* under treatment, such surges varying from about 11 per minute to about 50 per minute.

As long as these slow waves are called by the same name as the rapid waves there will be confusion. It cannot be too strongly urged that the name of rhythmic currents be applied to all rhythmically repeated surges of any current produced in periods adapted in their rhythm to the normal contraction periods of the part treated, the character of the rhythmic current being further indicated by the words "galvanic" or "nongalvanic."

We owe the first idea of rhythmic current surges in the upbuilding of muscular function chiefly to Professor Bergonie, of Bordeaux, France. Any attempt to imitate the normal periods of contraction had formerly to be made by the laborious process of turning a current on and off by hand, whether reversed when off or not, with resulting fatigue to the operator, inaccuracies, and too short duration of treatment. In former works the author gave elaborate directions for varying the force applied to a given part with some sort of rhythm by moving a soaped electrode pad back and forth or in a circular manner over motor points or muscles, but too often the practice has been to apply nonrhythmic currents of some kind so long in a given spot as to cause fatigue in motor structures.

Under the stimulus of Professor Bergonie's work, and more

recently by the extensive use of these currents in the reconstruction hospitals during and after the World War, we now have a number of machines on the market producing rhythmic sinusoidal waves of direct current and rhythmic surges of alternating current that have raised this feature of routine electrotherapy to an art of increasing exactness and value, greatly extending its field of usefulness. In the apparatus devised by Bergonie the faradic current was the basal current. This apparatus is now but little used on account of the limitations of that current, but the suggestion has resulted in the development of apparatus for the production of smooth waves for rhythmic synchronous stimulation of various organs that no electrotherapeutist, industrial surgeon, gynecologist or urologist can afford to be without.

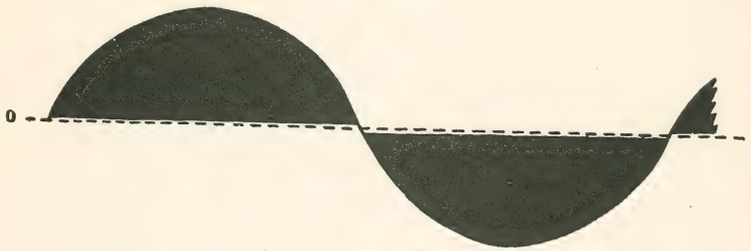


FIG. 34.—Diagram of Galvanic Sinusoidal Waves.

The rhythmic variation of the strength of the currents supplied by these machines should be timed to allow of a complete single-impulse or composite-impulse contraction of the nerve or muscle stimulated, followed by an ample period of no current in which the organ comes to rest before the next surge. The rhythmic surge, therefore, is a gradual and smooth increase, duration, and decrease of the single galvanic wave or more frequent alternating waves of the current employed, with a period of rest between surges, the whole movement being actuated by some mechanism. The surges are reversed between each rest period only of necessity when the current is galvanic and we wish to produce the deep penetration of galvanic alternative waves.

The time rate of rhythmic surges or alternations, and of the rest periods between the surges, is most important if the treatment is to stimulate or exercise a part without fatigue. The

various muscular organs of the body have rates of contraction during functionation peculiar to each organ or set of organs.

The muscles of the arms and legs contract at a rate well known to oarsmen and drill masters. This is from 30 to 40 per minute.

In the pelvic muscles the rate is probably about the same as that of the arms and legs.

The respiratory muscles contract and relax at the rate of 18 to 22 per minute.

Rhythmic surges applied percutaneously to the muscular coats of the intestinal tract cannot be so well gauged, as these are slow, progressive movements, that, once started by an adequate stimulus, tend to traverse a section of the intestine independent of time stimuli. Peristaltic action that will traverse many feet

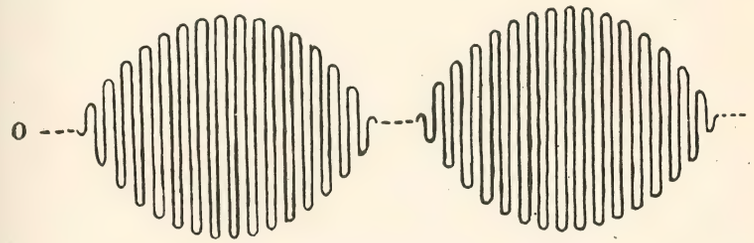


FIG. 35.—Diagram of Alternating Current Surges. (There are many more alternations in each surge, as usually made, than could be shown in the diagram.)

of the intestine can be stimulated by single surges, physiologists telling us that a peristaltic wave so started will always be propagated downwards, that is: will be a peristaltic wave and not an antiperistaltic wave. Ten to twelve surges per minute are practically single waves when the period of rest is considered, and this is doubtless the proper number when the attempt is made to arouse these muscles with the nongalvanic rhythmic surges. Galvanic alternate surges as slow as this give rise to more of a burning sensation than when faster. In stimulating peristaltic action the duration of the surge is also important, for as stated previously, smooth muscle fibers demand more current duration for response than striated muscles.

Further studies are needed in the normal contraction times of other muscles and muscular organs, such as the prostate, the uterus, etc., with a view to devising synchronous stimuli in rhythmic surges.

The Rhythmic Galvanic or Sinusoidal Current.—A rhythmic application of the direct current requires some form of machine to produce smooth, slow, alternate waves of a direct current passed through it. The direct current must be supplied to the machine from direct current mains, a motor generating set of motor and dynamo used for surgical ionization, or from a smaller motor generator attached to the apparatus.

The rhythmic waves thus produced (Fig. 34) should be of a frequency of 40 to 50 per minute (20 to 25 cycles) for the reason that if slower than this some ionization will be felt by the patient as a burning sensation when large currents are used, and if more rapid than 50 per minute will be apt to tire the part. With well

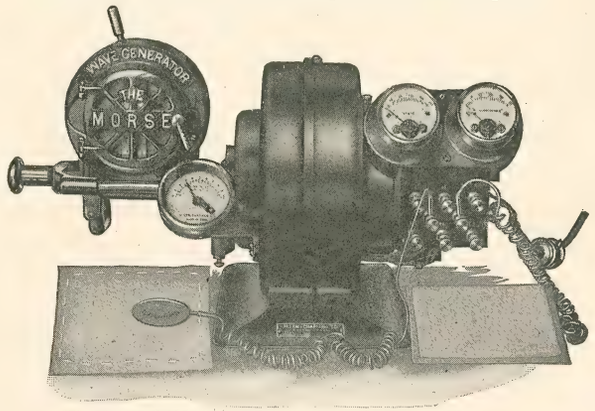


Fig. 36.—Morse Wave Generator.

adjusted kaolin electrodes of large size on the back and abdomen (Fig. 16) a patient accustomed to the sensation will be sensible of powerful contractions only at the rate mentioned, while slower ones will produce distinct burning sensations in addition to the contractions.

The author has contended for years at the meetings of the American Electrotherapeutic Association that such galvanic rhythmic waves are of particular value in the treatment of neurasthenia of abdominal origin, doubtless by an excitation either of the neurons of the sympathetic system or by direct stimulation of the suprarenal glands (endocrine stimulation?); also for the treatment of gastroptosis, enteroptosis, postoperative dystrophies and pelvic relaxations. For these purposes a smoothly produced alternate wave of 50 to 200 milliamperes is essential, together with the electrodes described.

A galvanic current of definite value is unquestionably produced by sinusoidal wave generators not supplied with a dynamo, when the currents are produced in overlapping waves that are all above the zero line and therefore galvanic, but these currents lack in smoothness and are therefore unsuited to the application of heavy amperages, and they are, moreover, not alternating and

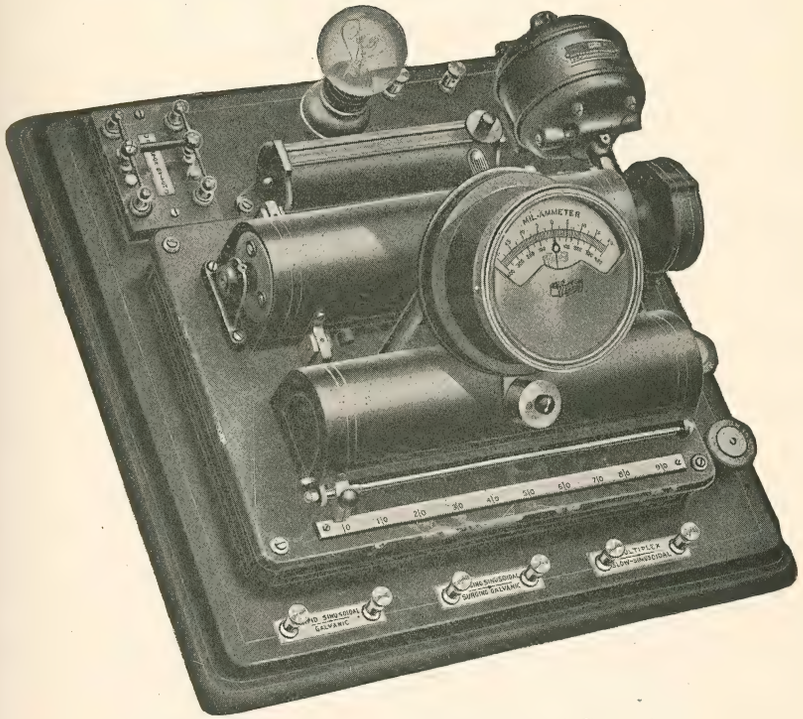


Fig. 37.—Victor Galvanic Sinusoidal Wave Generator.

therefore electrolytic. They are indicated when galvanic surges below 50 milliamperes are useful.

Rhythmic Surges of Nongalvanic Currents.—Some of the sinusoidal machines on the market produce rhythmic surges of nongalvanic wave currents that are valuable in stimulating the striated skeletal and other voluntary muscles and when powerful, the smooth fiber muscles also. These are of excellent service in the treatment of obesity by the Bergonie method. The shape of these nongalvanic surges is shown in Fig. 35. In some

machines the surges are alternated at each period of no current when the "slow sinusoidal" wave is used, but this is of course absurd, as there is no advantage in alternating a current that is already alternated. Mere surging of a current made up of alternate waves is all that is required to make it a surging rhythmic current.

In one of these machines (Fig. 36) the 42,000 alternate waves per minute are surged by the excellent expedient of a cam action

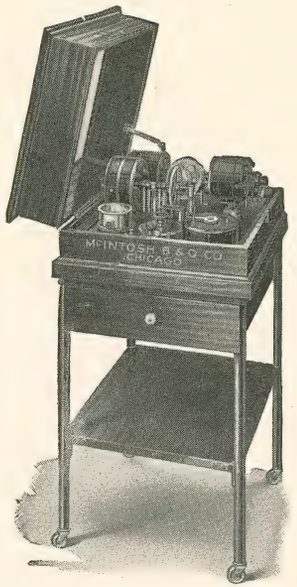


Fig. 38.—McIntosh Wave Generator.

that regulates the surges, one being able to select the frequency of the surges, from 11 per minute to 36 per minute by the momentary action of slipping out one cam and replacing it with another. These surges are remarkably free from irregularities that give pain to the patient, and the generator is so simple in action that it may be entrusted to a nurse.

Nongalvanic rhythmic surges have the advantage that they may be run somewhat slower than the galvanic without increased sensation, the slower rate being useful in weakened muscles. It is possible also that, giving rise to less pain in the atrophied

muscles of infantile paralysis (in which sensory nerves are always unaffected by the disease) they may be of more service in the middle stages of these atrophies.

Static Wave Currents.—These wave currents, which may now be obtained also in a rhythmic form by simple expedients, are fully described in Chapter IX. As they are composed more or less of condenser discharges they possess valuable physiologic and therapeutic effects.

CHAPTER VIII

HIGH FREQUENCY CURRENTS

Essential Parts of a High Frequency Generator—The High Pressure Transformer—The Condenser—The Spark Gap—The Oscillation Transformers—Resonance—Serial Action of the Several Units of a High Frequency Generator—Internal Circuits Within the Generator—Transformer Primary Circuit—Transformer Secondary-Spark Gap-Oscillation Primary Coil Circuit—Patient's Circuits—d'Arsonval Circuit—Tesla Circuits—Oudin Circuit—Hot Wire Meter—Portable High Frequency Generators—Directions for Operating the Generator—Vacuum Tube Thermopenetration—Non-vacuum Tube Thermopenetration—Medical Diathermy—The Physics of Diathermy—Diathermic Electrodes and Methods of Application—Therapeutic Effects of Medical Diathermy—Autocondensation—Autoconduction—Effluvation—Surgical High Frequency Modalities—Electrodesiccation—High Frequency Cauterization—Electrocoagulation.

High frequency currents are alternating waves of power, resembling low frequency alternating currents in this feature of alternating polarity, but they differ from ordinary alternating currents in two important respects: First, their frequency of alternation is invariably, in proper apparatus, *much beyond the minimum 500,000 waves per minute that can produce neuromuscular response,* as pointed out in the preceding chapter; and, second, because they are oscillatory in character, due to the interposition of a condenser in the circuit.

The application of high frequency currents in medicine was the suggestion of Professor d'Arsonval, seconded at an early date by Georges Apostoli.

ESSENTIAL PARTS OF A HIGH FREQUENCY GENERATOR

It is not wise for the writer on the essentials of high frequency apparatus and practice to attempt to describe too closely the constructional features of any high frequency generator now on the market, for these generators are yet in process of perfection

and any now described may be shortly modified in great measure.

Each such apparatus, nevertheless, must consist of certain definite units, and the student proposing to make a correct use of these currents should comprehend the action and interaction of these units. Generators should be built to facilitate an examination of their inner structure. Removable sides and ends are fortunately more common than formerly.

The essential parts of a high frequency generator are: *the high pressure transformer; the condenser; the spark gap;* and either one or two *oscillation transformers.* These comprise the units of a complete generator for use with the alternating current street lighting supply. If the direct current supply of power

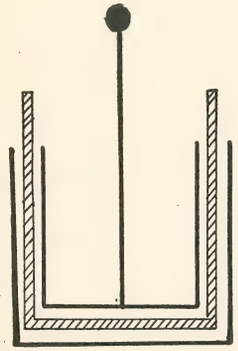


FIG. 39.—Leyden Jar Condenser.

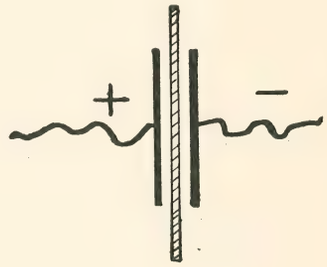


FIG. 40.—Franklin Pane Condenser.

is the only one available a motor generator to turn this supply into the alternating current will be needed.

The High Pressure Transformer.—On the switchboard of the usual generator a pair of binding posts will be seen for attachment of the two conducting wires from the wall or baseboard supply fixture of the power line mains, or from the DC-AC motor generator if the latter is needed. A third binding post is usually placed here for connecting a ground wire to the water pipes, outside copper lightning rod, or other effective "ground." Within the case, wires lead from the binding posts to the main power switch, and thence to the resistance controller switch of the high pressure transformer, the latter resting on the floor of the closed cabinet usually, as it is dangerous to come into contact with it when in operation.

This transformer is what is known as of the closed circuit, magnetic leakage type, stepping up the voltage of the street current by induction. It should be oil immersed. Its action is to step up the 110 volt alternating current from the electric light circuit to between 3,000 and 4,000 volts, the controller switch permitting a gradual increase as desired by cutting out wire resistances located in the case in the rear of the switch, the whole resistance being in circuit when the switch is on the first button, less when on the second button, and so on. The current delivered by this transformer to the condenser from its secondary winding is increased in *voltage* but not in *frequency*.

The Condenser.—In circuit with the *secondary winding* of the transformer described briefly above is placed the condenser and spark gap. As both these units are central features of high frequency generators a more detailed description of their principles of action is necessary. The original form of condenser

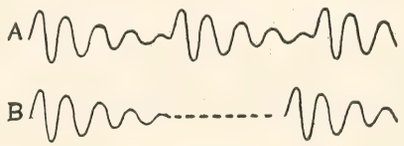


Fig. 41.—Diagrams of Condenser Oscillations. At B the groups of oscillations have too long an interval between them, due to a defective spark gap.

was the Leyden jar (Fig. 39). The simplest form of condenser, now much used in high frequency apparatus, is similar to that devised by Franklin and called since the Franklin pane. This consists of a pane of glass (Fig. 40), on either side of which is pasted a layer of tin foil, the metal being smaller than the glass to prevent sparking between the two layers of tin foil over the edge of the glass. *The glass or other dielectric is the essential medium for holding the charge in the condenser.* When the opposite metal surfaces are connected with the opposite poles of a source of high voltage electric power supply, electric energy in balanced charges is stored in the condenser as the current flows from the generating source, in a manner somewhat analogous to the storage battery, save that high voltage currents are only suitable for condenser storage, and that the physical storage is not chemical, as in the storage cell, but by *ether strain in balanced charge in the substance of the glass or other dielectric itself.* When the capacity of the condenser (measured in fractions of a microfarad) is reached, and conductors attached to the two coatings are brought within a suitable distance of each other in a spark gap, the condenser discharges by a series of oscillations in decreasing amplitude until the charge is dissipated, the condenser being then immediately recharged by the secondary coil of the transformer and the process repeated.

These condenser oscillations (Fig. 41) are said to occur in the $\frac{1}{10000}$ part of a second and there may be 100,000 or more per second when a proper spark gap is employed. This current is therefore greatly increased in frequency when delivered to the next unit, the oscillation transformer. If, however, the groups

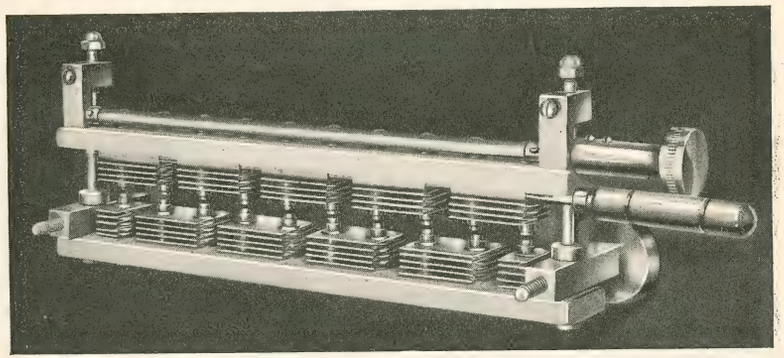


Fig. 42.—Ten Point, Tungsten Tipped Spark Gap. The current is controlled in two ways in this spark gap: By withdrawing the slide rod to add to the gaps and pushing it in to lessen them; 2, by a rotary control to adjust the length of the gaps.

of oscillations have too long intervals between them, due to too long intervals between transformer recharges, as in B, Fig. 41, the diathermic efficiency of the current is lessened since the circuit is idle during a portion of the time, and the patient also may feel the "faradic effect"—a neuromuscular stimulus.

The Spark Gap.—The spark gap is really a portion of the condenser unit assembly, for it is the spot at which the condenser oscillatory discharge occurs. It is placed "in shunt" with the secondary winding of the high pressure transformer and also in shunt with the condenser. That is: the secondary of the transformer may discharge through it without charging the condenser if the resistance in the air gap is low enough; and it discharges the condenser immediately on the condenser charge reaching

a point high enough to break down the resistance of the air. The wider the gap, therefore, the higher the condenser discharges and the stronger is the high frequency current delivered from the oscillation transformer to be described later.

The fact that the high pressure transformer may discharge directly through the spark gap as stated above, without charging the condenser, when the condenser discharge heats the air between the gap surfaces and makes it a better conductor, is a disadvantage, as it prevents the continuous recharging of the condenser. This difficulty has led to a variety of designs of spark gap intended to obviate this fault, for if the transformer fails to keep the condenser charged there will be gaps in the oscillatory current and the patient will experience the faradic

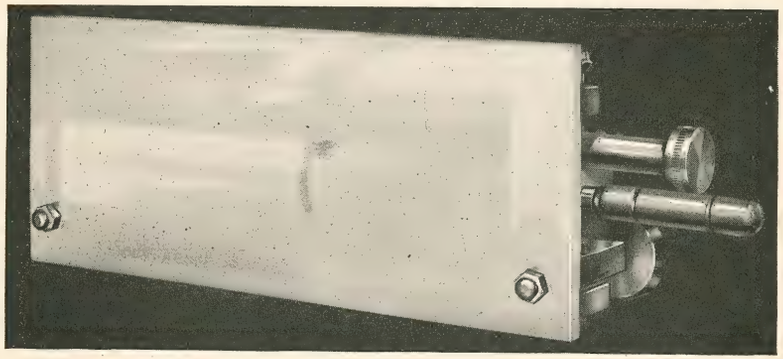


Fig. 43.—The Spark Gap with White Glass Protective Cover.

effect of a poor high frequency current shown in Fig. 41, B. Devices for blowing away the arc of hot air, rotating one side of the spark gap, etc., have been employed, but the best device at present is the multiple spark gap of de Kraft, which presents so large a heat radiating surface, consisting of ridges of metal, that heating and lost efficiency are greatly lessened. Such a spark gap consists of a series of gaps, the total length of air space for the current to leap across being the length of each gap in action added together. In use, a sliding contact cuts out all but the first gap at the beginning of the treatment or when a small current is desired, the length of the gap being increased for greater current by withdrawing the sliding rod to place other gaps in action.

Spark gaps are the most troublesome parts of a high fre-

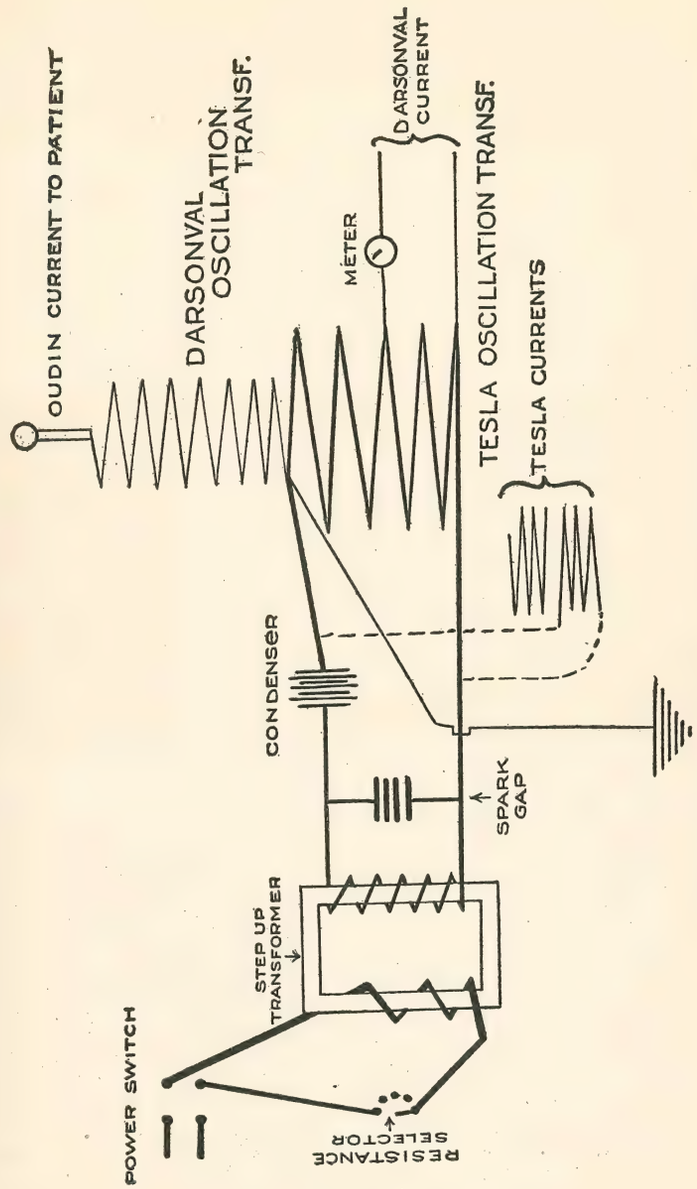


Fig. 44.—Wiring "Hook Up" of a High Frequency Generator.

quency generator to maintain in efficient condition, and attempts are now being made to design a generator that will substitute for it a vacuum tube, like that employed in radio broadcasting, but without success at the time of going to press.

The Oscillation Transformers.—The oscillatory discharge of the condenser across the spark gap sets up a current of very high frequency in this circuit. This is raised to the greater high frequency and greater voltage desired by including it *in the primary of another transformer* (Fig. 44), and placing within the induction influence of this latter primary a secondary coil having a number of turns capable of stepping up the high frequency oscillations still further to the point desired for the particular work to be done. This oscillatory transformer may be of either the d'Arsonval resonator type or the Tesla inductor type. Both types are usually contained in the HF generators supplied by manufacturers, but are never operated at the same time, provision being made by a selector switch and labeled terminals for the selection of either the d'Arsonval or Tesla current to suit the particular application. Both operator and patient are protected from accidental grounds through their persons by a ground wire as shown in the illustration, which should be invariably connected with a ground in moist earth, such as a copper lightning rod outside the house or a gas or water pipe.[1]

Resonance.—The d'Arsonval oscillation transformer is known as a resonator, since the currents in the upper and lower helices of this transformer may be made to vibrate in syntony by proper adjustment of the two. By manipulating the adjustable arm contact on the turns of the lower solenoid of large wire (*when the patient is not in circuit*), the upper solenoid may be made to vibrate in resonance to the power flowing through the lower coil, just as one tuning fork will vibrate in unison with another near it. This resonance or vibration syntony has the effect of increasing the frequencies of the output of the Oudin coil.

Serial Action of the Several Units of a High Frequency Generator.– A reference to Fig. 44 will show that a high frequency generator will comprise the following units, and act as follows:

[1] It is important that the floor beneath the operator and patient be of a material that will not permit grounding of the current, such as linoleum. In its absence a rubber mat should be placed beneath generator, operator and patient. Tile, concrete or wood floors are not insulators.

The Transformer, which converts the low voltage current available from the AC lighting circuit or motor generator into a high voltage current suitable for charging

The Condenser, which is composed of alternate sheets of metal and glass, the latter having a high dielectric value. The condenser discharges its load of electric energy at high pressure across

The Spark Gap, which is composed of a series of metallic discs insulated from each other and with minute air spaces between them to permit a shorter or longer total spark length. In series with condenser and spark gap is the primary of

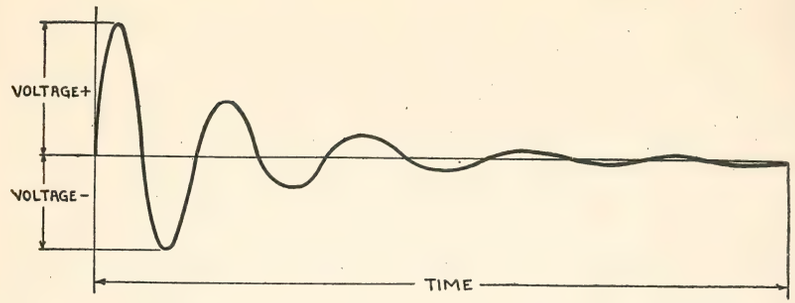
The Oscillation Transformer, the d'Arsonval type of which comprises two coils or helices of copper wire. One of these coils, the primary, is composed of a few turns of thick wire while the secondary may have from ten to one hundred times as many turns of fine wire. In this type the primary and secondary coils are connected at a neutral point, which should be grounded. The Tesla type consists of somewhat similar primary and secondary coils. There is no metallic connection between the two coils of the Tesla type, but only by induction.

Tracing out the wiring diagram shown in Fig. 44 it will be seen that there are two interior circuits in the generator which do not reach the patient, and four oscillation circuits of which the patient forms a part, one only of which can be used at a time. A study of these circuits will help in an understanding of the currents traversing them:

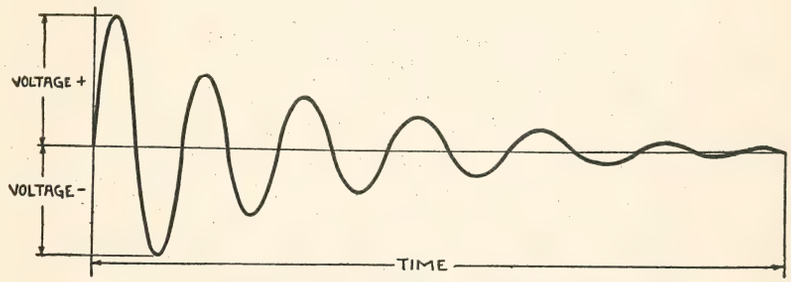
INTERNAL CIRCUITS WITHIN THE GENERATOR

The Transformer Primary Circuit.—The first circuit of wiring begins at one pole of the main switch, passes through the resistances in circuit at the controller and the primary coil of the step-up transformer and returns to the other pole of the main switch, and thence to the first pole through the power mains. It is all metal, carries only the 110 volt, 60 cycle current of the lighting mains, and does not come into contact with the patient.

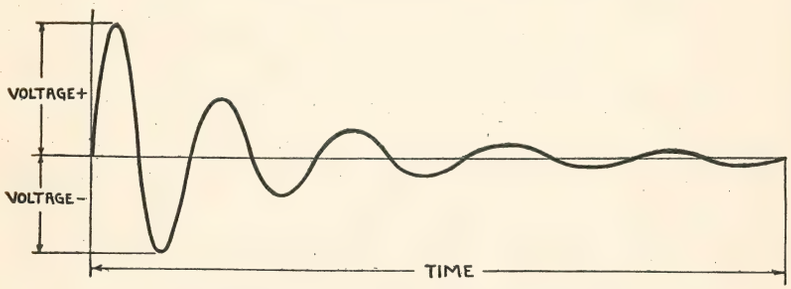
The Transformer Secondary-Spark Gap-Oscillation Primary Coil Circuit.—The second circuit of wiring traverses the secondary coil of the transformer, passing thence through the condenser and spark gap and, by a shunt path, through the primary of the oscillation transformer, returning to the other



D'ARSONVAL WAVE CHARACTERISTIC



TESLA WAVE CHARACTERISTIC



OUDIN WAVE CHARACTERISTIC

FIG. 45.—Diagrams of Oscillation Characteristics. The d'Arsonval wave is said to reach a maximum voltage of approximately 50,000, and the time period, as shown in the sketch, indicates approximately 1/10,000 of a second.

The Tesla wave reaches a maximum voltage of 400,000 volts in the same time.

The Oudin wave reaches a maximum voltage of 600,000 volts in the same time period.

end of the secondary coil of the voltage transformer. It is all metal save for the air spaces at the spark gap and the dielectric in the condenser, and carries a dangerously powerful current.

The current in this circuit is raised in potential by the condenser from that received from the high pressure transformer to a distinctly high potential-high frequency current, with dangerous qualities because of the iron core in the high pressure transformer, but none of it can reach the patient in any proper arrangement of the electrodes and patient unless the spark gap is actually touched.

PATIENT'S CIRCUITS

The d'Arsonval Circuit.—The d'Arsonval circuit of the d'Arsonval resonator oscillation transformer begins at the point of contact of the sliding arm with the coarse primary solenoid of this transformer, passes through the hot wire meter, conducting wire and active electrode to patient, through the patient to the dispersing electrode, and thence back to the base of the primary solenoid. It will be seen that this circuit apparently includes a portion of the dangerous transformer-condenser circuit, but none of the transformer-condenser current traverses the patient for two reasons: 1. The two paths present such enormous differences of resistance—the large copper wire of the coil so little and the patient so much more—that all of this comparatively low volt current of the transformer-condenser circuit will pass through the copper wire. 2. The d'Arsonval helix has such an enormous self-inductance that the d'Arsonval current produced in it *is forced to traverse the patient, in spite of the immensely greater resistance apparently presented by the body tissues compared with the few inches of copper wire in the coil, for the reason that the self-inductance itself presents an enormous resistance, amounting to a perfect barrier to the return of the d'Arsonval current backwards through the coil in which it is generated.*

The d'Arsonval current thus produced by the self-inductance of the few turns of the d'Arsonval solenoid charged from the condenser, as described, possesses the largest amperage of any high frequency current, hence is most valuable for diathermy, both medical and surgical, and is also frequently used in auto-condensation. The hot wire meter should be invariably included in this circuit to indicate the milliamperage used, which ranges

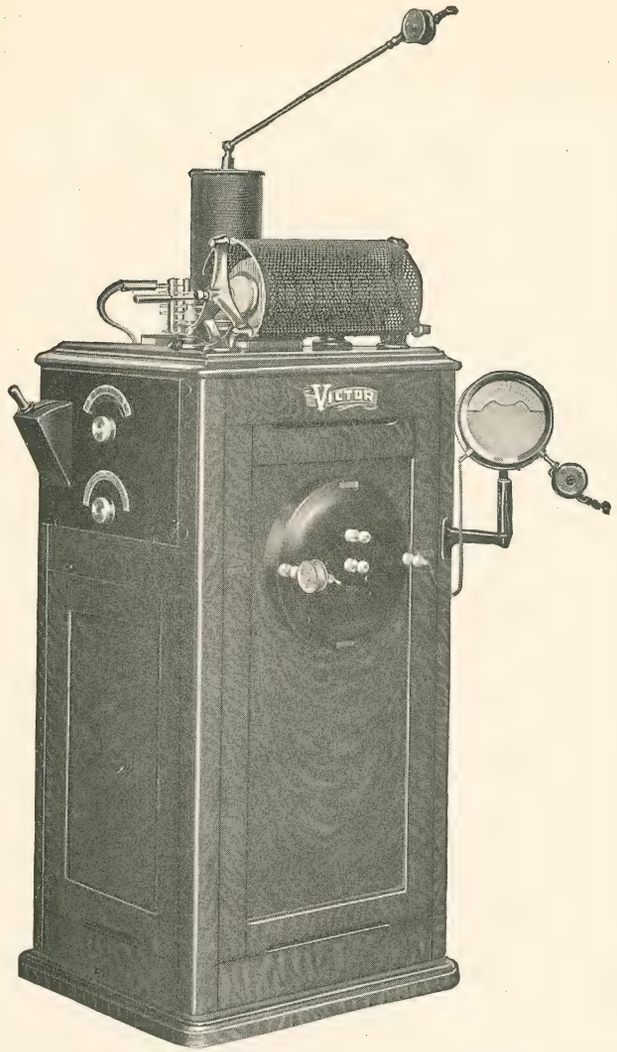


Fig. 46.—Victor High Frequency Generator.

from 100 to 2,500 milliamperes or more. It does not possess the highest voltage or the highest frequency compared with the Tesla and Oudin circuits, but is nevertheless a true high frequency current. It is employed in bipolar applications only.

One of the chief reasons why this current, as well as the Tesla and Oudin currents, presents no danger to life, aside from their heat effects (page 107), is that *neither of the coils in*

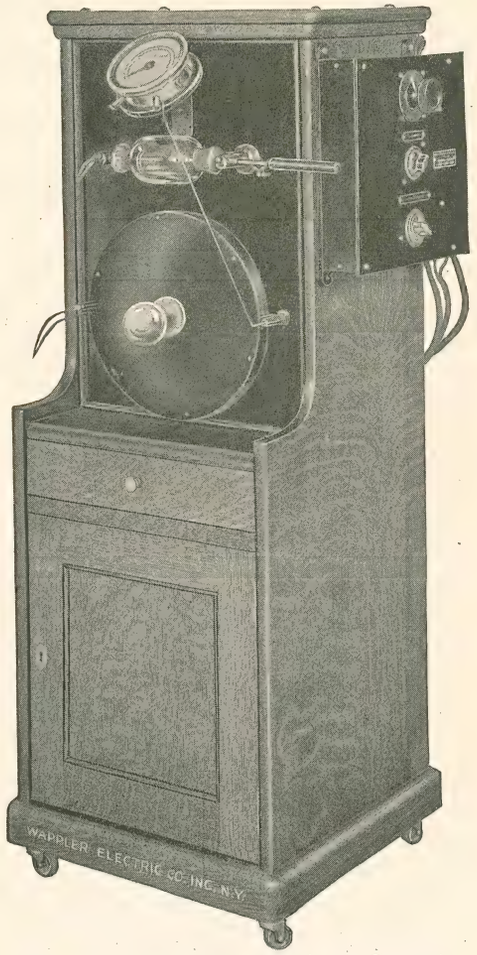


Fig. 47.—Wappler High Frequency Generator.

which they originate has a metal core. This not only eliminates all danger in their use, but makes it possible to start and stop them by manipulating the main power switch on or off with the electrodes in position on the patient and the current partly

turned on without real shock to the patient. This is not true of any other therapeutic current. Only a high frequency current can be produced in these circuits.

While it is true that, as just stated, the turning on and off of a properly generated high frequency current should be shockless as well as free from danger to the patient *except when the solenoid contact is moved,* it should not be overlooked that there is ample opportunity for a careless operator to produce a painful

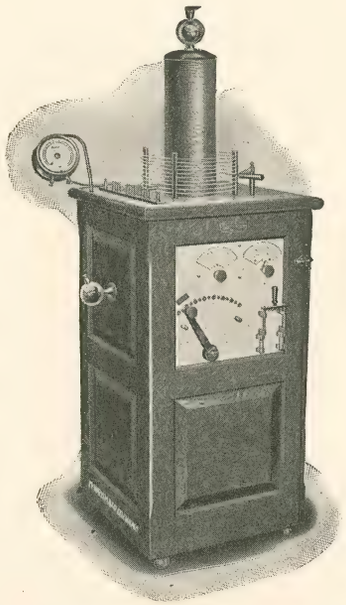


Fig. 48.—McIntosh High Frequency Generator.

burn by allowing an arc to form between an electrode or a conducting wire and the patient's skin. Like any other arc of highly heated air, this will scorch the patient's skin unpleasantly. To avoid such accidents the electrodes should be in place on the patient before the current is turned on and remain in place until it is turned off, and the conducting wire should not be allowed to remain too near the skin. The contact arm of the d'Arsonval solenoid particularly should not be manipulated unless the main power switch is "off."

The Tesla Circuits.—As will be seen by referring to the diagram, Fig. 44, the Tesla oscillation transformer possesses also a primary circuit, employed bipolar with hot wire meter in circuit; and a secondary circuit, employed unipolar. The primary Tesla circuit produces a current with less amperage than the d'Arsonval but greater voltage. This adapts it to some autocondensation applications, for it produces greater heat wattage than the d'Arsonval though the meter may show less milliamperage in action. The unipolar Tesla circuit produces a hotter vacuum tube and nonvacuum tube current than the Oudin,

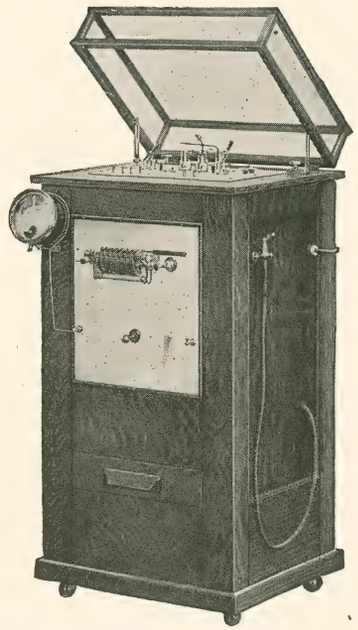


Fig. 49.—Thompson Plaster High Frequency Generator.

and surgical diathermy of less heat, intensity and destructive action than the bipolar d'Arsonval circuit.

The unipolar Tesla circuit, like the Oudin circuit, in reality completes its circuit through the air, floor, walls, etc., to the other pole of its oscillation coil, and is thus in a sense a complete circuit, but the air portion is of such enormous resistance that it is for all practical purposes unipolar.

The Oudin Circuit.—The current of the Oudin circuit is produced in the Oudin resonator, a prolongation of fine wire above the d'Arsonval primary solenoid, and is usually so called, though a portion of the d'Arsonval oscillation transformer, because it is the circuit of a high frequency transformer-generator that most closely resembles the original Oudin current, produced by a resonator charged by static machine condensers. The current is taken from the top of the resonator only, and is unipolar

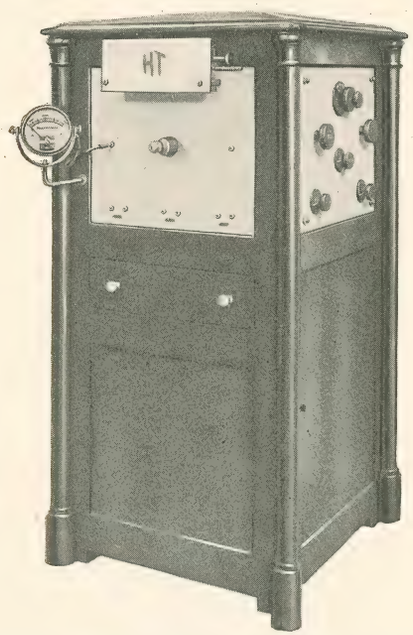


FIG. 50.—High Tension Company's High Frequency Generator.

in the same sense as that employed in describing the unipolar Tesla current.

The Oudin current has the least amperage and the greatest voltage of any high frequency current, and is therefore best adapted to light vacuum tube and nonvacuum tube applications and to the electrodesiccation of the smallest growths.

The Hot Wire Meter.—This meter is included in the circuit only when nonvacuum thermopenetration, diathermy, autocondensation or surgical diathermy is employed, and indicates the mean average of the milliamperage of the current actually

traversing the tissues. This form of meter is constructed on the principle of the elongation of a fine wire by heat, being calibrated to show the current amperage producing the heat. The ordinary type of meter will not show the strength of an alternating current. The wire mechanism within this meter is necessarily delicate, and may be burnt out by an accidental contact between the conducting wires or electrodes carrying a proper current to the patient, the short circuit thus made through the meter increasing the load on the hot wire to the fusing point. This accident may even happen when the wires are allowed to approach near enough to permit an arc between them. The resulting damage affects the meter only.

Portable High Frequency Generators.—The description of the essential parts of a high frequency generator in preceding pages applies to the large cabinets, that are more or less immovable. Smaller, portable high frequency generators are used by many physicians quite successfully in energizing vacuum and nonvacuum tubes and in the desiccation of moles, warts, etc.; but these instruments are usually not well adapted to diathermy or autocondensation, though one manufacturer markets a portable apparatus that is said to furnish 2,000 milliamperes in the d'Arsonval circuit.

The step-up transformer of these generators is not oil immersed, and the condenser is compactly built. Their spark gaps are less well adapted to the higher frequencies than are those of large generators and the d'Arsonval milliamperage is less.

The Radiotherm. A Hot Knife H. F. Generator.—Wappler has recently put on the market a high frequency generator in which large radio tubes replace the spark gap, thus producing a current quite free from faradic effects. This current is excellent for severing living tissue bloodlessly, as stated in Chapter VI, one pole being connected with a scalpel on an insulated handle and the other with a dispersing plate, but it has not yet been adequately tested in electro-coagulation.

OPERATION OF A HIGH FREQUENCY GENERATOR

Directions for Operating the Generator.—Before attaching electrodes to patient observe that the power switch is *open,* spark gap *closed,* resistance controller switch on low stud, and that the selector switch points to the current desired. The electrode cord reels should also be in the proper terminal sockets of the current to be used. It is my habit to relieve the spring tension

of the reels on the cords after sufficient unwinding of the latter by plugging the cord exit from the reels by small wooden plugs —match sticks.

To Start the Current.—1. With main power switch open and spark gap closed, put electrode or electrodes in position on patient, and see that the conducting cords do not touch the patient and cannot readily do so; that they are not too close together, or resting on a metal table or couch.

2. Turn controller switch, controlling the resistances of the transformer, to the point probably needed in the application. In ordinary applications it is best on point 1. This switch may be advanced or turned back later during flow of current as needed.

3. Close main power switch.

4. Draw out rod of spark gap gradually to the point that will give the strength of current desired.

To Turn Current Off.—1. Close spark gap by pushing rod in.

2. Open main switch.

3. Disconnect electrodes and remove them from the patient.

4. Turn back controller switch in readiness for next use of apparatus.

Caution.—The patient is electrically charged during all applications and therefore receives a slight shock by a grounding arc should the operator or any other person approach into too close proximity. Do not remove the adjustable arm contact of the d'Arsonval solenoid from the solenoid during treatment of patient as a most unpleasant shock will result.

THERMOPENETRATION

Vacuum Tube Thermopenetration.—The vacuum tube is a tube or bulb of thin glass from which the manufacturer pumps nearly all the air until more or less of a vacuum results. In such a vacuum the remaining air molecules are capable of conveying the high voltage, high frequency current from a metal band embracing the outside of one end of the tube, through the vacuum and both layers of glass to the surface of the body into which it penetrates deeply.[1] The current is conveyed through

[1] It is probable that a better explanation of the action of the vacuum tube is that the vacuum acts as a dielectric of a condenser, with the metal band as one coating and the patient's body as the other. This is the only explanation of the action of the non-vacuum tube, the current from this being stronger than that from the vacuum tube because the single layer of glass acts as a better dielectric.

the vacuum as a cathode stream of electrons, the color produced by the stream in the tube varying from a reddish purple in tubes with the lowest vacuum through shades of green to yellow, the latter with the highest vacuum. Some weak X-rays are radiated from tubes with the highest vacuum.

Electrodes with a medium vacuum are usually employed.

Since the development of the non-vacuum tube electrode the vacuum tube is mostly restricted to surface applications, as accidental break-down of vacuum tubes within body cavities have been reported, with most unpleasant or even serious consequences in removing the broken fragments. The electrode is attached to an insulating handle by which the patient or operator holds it in contact with the part of the body to be treated.

Both variety of electrodes are connected by a suitable conductor with the Oudin terminal at the top of the Oudin resonator for the lighter applications, or to the unipolar Tesla terminal for the heavier applications, the electrode being placed in position on the skin and the proper connections made before the current is turned on at the power switch and spark gap.

Surface and deeper hyperemia being the aim in these applications, the electrode is held in position until the heat becomes unpleasant when it is shifted a little to one side, the motion being often possible without breaking contact, though the moisture drawn from the skin by the application often makes it sticky. It is usually better to open the power switch and reapply to the new location. Some operators employ these currents through a layer of clothing, or with an air space between the electrode and the skin, both being somewhat painful and certainly causing less penetration of heat to the subdermic structures than the direct application to the surface. To put powder on the skin possibly lessens the penetration until it becomes moist. Static sparks or effluves are preferable for surface revulsive effects if one has a static generator.

The physics of such applications is probably the conversion of the current into heat alone, though it is not certain but that other than heat effects are obtained from them.

Therapeutically, these applications produce valuable hyperemic stimulation of surface and deeper structures, such as weakened hair roots, indolent inflammatory conditions on and beneath the skin and mucous membranes, bruises and sprains, including subdermic effusions in the orbit, and many other conditions in

the practice of gynecology, dermatology and general office work.

It is unfortunate that these currents have been employed by ignorant persons under the misleading name "violet ray," for no ultra violet rays are produced by the electrode, and if

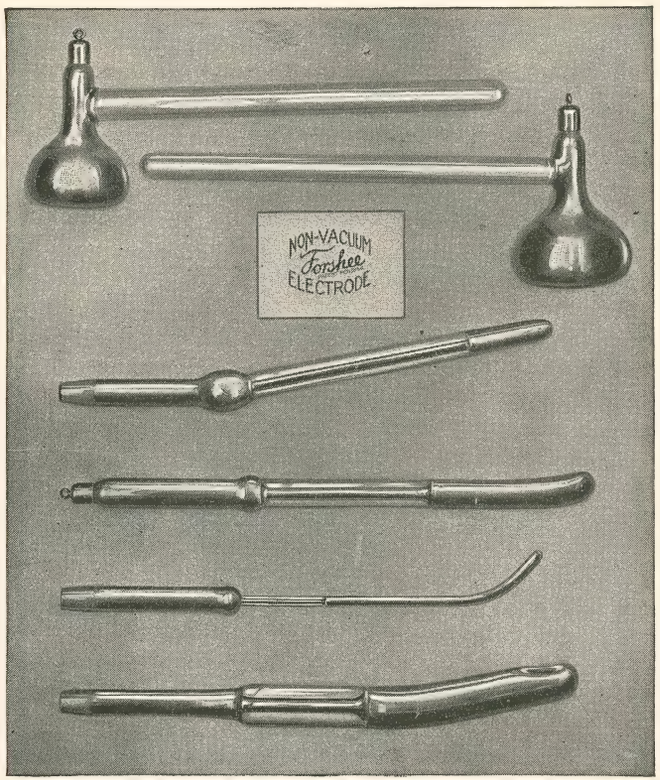


FIG. 51.—Set of Non-Vacuum Tube Electrodes.

they were produced the glass wall of the tube would retain them inside and they would not reach the patient.

Non-vacuum Tube Thermopenetration.—These instruments are silvered on the inner side of the glass, which is opened to the air (Fig. 51). The effect is a more powerful condenser current than that of the vacuum tube variety, for the reason that a simple dielectric of glass has more capacity as a condenser than a

combined glass-and-vacuum dielectric. A greater degree of heat can be applied to a part by a non-vacuum type therefore, together with any other possible conversion effects that may be conveyed into the body by these instruments, and they are safely employed within the body cavities when insulated by the fused glass open tube jackets that are a necessary feature in all electrodes for properly localized internal applications. This insulation by the open air and glass jacket extends between the space on the electrode where connection is made with the generator to the portion in contact with the internal organ to be treated, protecting the sensitive external mucocutaneous outlets from the heat effects and concentrating them at the point desired.

The fact that the outer sensitive portions of the vagina, urethra or rectum are thus protected from the current enjoins care that a too high degree of heat be not applied to the insensitive parts within, for patients will often say that they do not feel quite a high degree of heat in the upper portion of the vagina. Usually the first stud of the controller and one or two gaps of the multiple gap are sufficient. A duration of application of five to ten minutes in one position of the electrode is sufficient unless a very low degree of heat is employed.

Captain Sampson has recently shown that the effect of a vacuum or non-vacuum tube current may be increased and localized by the operator touching an opposite part of the body with his hand, thus attracting the current by a better return circuit into a deeper and more direct penetration between the two points. The hand should be placed in position before the current is turned on and kept in position until it is turned off.

MEDICAL DIATHERMY, OR ENDOTHERMY

The modalities previously described, the vacuum tube and non-vacuum tube thermopenetrations, are unipolar applications in the sense that but one electrode is placed on the body, connected with but one pole of the generator. The air-floor-earth completion of this circuit presents so great a resistance that but moderate thermopenetration occurs, immediately beneath the electrode, from which point it radiates widely.

For true diathermy, or through and through development of a greater heat, the d'Arsonval current is employed, with an electrode attached to each terminal, placed preferably on opposite sides of, or, in a limb, above and below the body or organ to be

diathermized, and with a meter in circuit with the patient to indicate the exact volume in milliamperes that is passing through the patient.

In external applications the electrodes consist of smooth, thin sheets of tin-lead alloy metal, or of tinfoil, connected with a terminal on the generator and meter by suitable conductors. If the spot to be reached is near one surface of the body the electrode on this side is made "active" by being smaller, and thus concentrating the lines of flow beneath it. The plates should be held in close contact with the body by a bandage, shotbags, sandbags or otherwise, care being observed that no ridge or edge is in better contact with the skin than the plate surface, or a blister will form at such spot. The conductors should be kept from contact with the body.

For small, irregular surfaces, such as the finger joints, the toes, etc., several layers of thin tinfoil are best, the upper plates being kept in position by shot bags smaller than the plate and not too full of shot, producing thus equal compression except at the edges. A conductor of No. 28 wire may be attached to the upper and lower tinfoil plates by adhesive plaster.

The Physics of Diathermy.—It should be understood in the first place that the peculiar advantage of diathermic applications in both medicine and surgery flows from the following fact: That the high frequency form of electric power enables us to *develop within the tissues themselves, throughout the circuit, any degree of heat from the transformed power desired, without the other effects that accompany direct and low-frequency wave currents.* Ampere for ampere the heat effect of all these currents is the same though diffused differently within the body; but the other effects restrict our use of through-and-through heat thus produced to the high frequency form in medical applications, though not in surgery.[1]

Heat is developed in the body or tissue conductor by an electric current as a result of the resistance encountered, as shown in Chapter VI. With a fixed resistance in a definite part of the body and definite sized electrode contacts, an increase of current will produce a direct increase of heat. A small, narrow conductor can be readily raised in temperature by a current of relatively small volume, but the human body, being broad and a fairly good conductor of electricity (i.e., presenting little resistance, comparatively speaking), requires currents of large volume when the relatively low pressure d'Arsonval current is used. Both the Oudin and Tesla currents are stepped up in the oscillation transformers to a far higher voltage than the d'Arsonval though the frequencies of all three may be the same. A fraction of a milliampere in the Oudin or Tesla unipolar circuits will produce more heat in proportion to their amperage than the same milliamperage in the d'Arsonval current because both Oudin and Tesla currents are much higher in voltage. But neither of the latter currents is able to compete with the lower voltage, lower internal resistance d'Arsonval current in heating large structures of low resistance with its great amperage.

[1] The direct current, applied with both poles in a malignant growth, as in the author's method, is an instance in which the direct, low volt current will at times be found to be superior to the d'Arsonval current in the electrothermic destruction of large growths if the same or similar amperage is used.

An excellent illustration of the temperatures attained in diathermized tissues may be obtained by passing the d'Arsonval current through a potato or piece of meat, the latter being best when quite fresh. A thermometer is placed in the center of the potato or meat to show the temperatures midway between the electrodes. The following account of such experiments is quoted from the recent and most excellent work by Dr. F. Howard Humphris, of London.[1]

Experiment with Potato.—The electrodes were pieces of tinfoil 2 by 1½ inches, fastened to each end. Midway between the two ends was a hole into which was placed a thermometer.

Time	*Milliamperes*	*Temperature in Degrees Fahrenheit*
Before the current was applied	....	70
After 1 min. 30 sec.	900	80
" 3 "	950	90
" 4 " 30 "	1000	100
" 6 " 30 "	1050	110
" 8 " 30 "	1100	120
" 9 " 30 "	1100	125
" 10 " 30 "	1100	130
" 11 " Current stopped for observation. Potato very warm.		
After 11 min. 45 sec.	1100	135
" 12 " 45 "	1100	140
Odor of potato cooking became noticeable		

[1] "Electrotherapeutics for Practitioners," by F. Howard Humphris, published by Henry Frowde; Hodder & Stoughton, London, 1921.

Time	Milliamperes	Temperature in Degrees Fahrenheit
After 13 min. 45 sec.	1150	145
" 14 " 45 "	1150	150
" 16 "	1150	155
" 17 " 5 "	1150	160
" 18 " 20 "	1200	165
Removed milliampere meter, as it was calibrated to 1200 only.		
After 19 min. 30 sec. milliamperage above....	1200	170
" 20 " 30 "	....	175
" 21 " 30 "	....	180
" 22 " 50 "	....	185
" 24 " 10 "	....	190
" 25 " 30 "	....	195
Potato began to steam, through faulty contact of electrode.		
" 26 " 55 "	....	200
" 28 " 25 "	....	205
" 30 " 25 "	....	210
" 31 " 10 "	....	212
" 32 " 10 "	....	215

EXPERIMENT WITH STEAK

Before the current was applied.....	....	56.5
After 1 min, 30 sec.	880	60
" 2 " 20 "	900	65
" 3 " 25 "	940	70
" 4 " 25 "	970	75
" 5 " 30 "	1000	80
" 6 " 35 "	1020	85
" 7 " 45 "	1030	90
" 8 " 55 "	1040	95
" 10 " 15 "	1050	100
" 11 " 30 "	1080	105
" 13 "	1110	110
" 14 "	1150	115
" 15 " 20 "	1170	120
" 16 " 40 "	1180	125
" 18 "	1200	130 *
" 20 " 40 "	....	135
" 22 " 10 "	....	140
" 23 " 40 "	....	145
" 25 " 10 "	....	155 †
" 28 " 10 "	....	165
" 29 " 50 "	....	170

* At 150 degrees it was noted that the juice began to flow from the incision for the thermometer.

† Irregularities of time and temperature readings are due to the removal of the meter from the circuit (range 1200).

Time	Milliamperes	Temperature in Degrees Fahrenheit
After 31 min. 5 sec.	....	175
" 32 " 30 "	....	180
" 35 " 40 "	....	185
" 35 " 15 "	....	190
" 36 " 25 "	....	195
" 37 " 40 "	....	200
" 39 "	....	205
" 40 " 40 "	....	210 ‡
" 41 " 40 "	....	212
" 45 "	....	214
" 47 "	....	215

‡ Juice was noted flowing freely from the four surfaces not covered by the electrodes.

At the completion of the test the surface of the meat had a reddish appearance; however, investigation proved that the inside was thoroughly cooked; it had the appearance of very much overdone meat.

The path of the diathermic current is supposed to be more direct than is that of low volt currents. This may be illustrated by considering the varying flow of a stream of water at low pressure and at high pressure down a staircase of concentrically curved steps, each step presenting an edge that is the half of a circle (Fig. 52). If these steps be absolutely horizontal at their edges the water from the low pressure stream at the top step will spread out and trickle over each edge of each step in a nearly even flow, widening and becoming more diffused at each step. When the pressure of the water current supply at the top step is very materially increased the tendency of the current will be to flow more and more down the middle of the steps. When the pressure is as great as that from a high pressure fire main it will shoot directly down the center of the steps (Fig. 53).

Now, if the edges of the steps in the two figures be taken as representing the lines of equal potential in a broad conductor such as the human body, across which the lines of electrons flow at right angles, the first figure (Fig. 52) represents exactly what occurs when a low volt current flows from a small electrode placed on the side of the body to a broad dispersing electrode on the opposite side, the current spreading out into a cone shaped path; while Fig. 53 represents the far more direct flow of a high frequency current through the body from a small portal of entry.

The comparatively direct path of the high frequency current through a moist conductor may be seen by the eye when we slice a large potato through the middle longitudinally after a

heavy d'Arsonval current has been sent through it from end to end for some time. There will be ocular evidence that greater cooking has occurred in the direct line of the current, though the whole potato be heated.

The value of this relatively direct path of high frequency currents through the body in enabling us to apply diathermy to internal organs is evident. To achieve this purpose requires special selection and placing of the electrodes. To reach the organ most directly the electrode plate should be smaller on the surface of the body nearest it than is the dispersing plate, and the plates

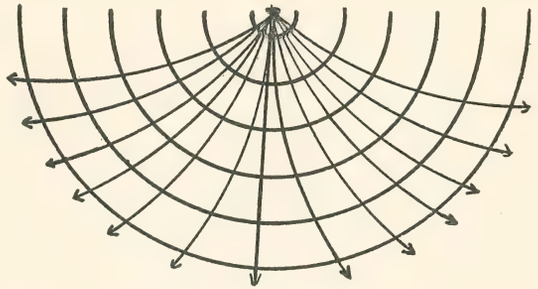


FIG. 52.—Diagram Illustrating the Flow of a Low Pressure Water or Electric Current Down Curved Steps or Down Curved Planes of Potential.

should be as nearly opposite each other as possible (Fig. 54). If the electrodes are not placed nearly opposite each other we may have an improper localizing of the internal density and greater heat and hyperemia than is desired, with possibilities of overheating and damage. This is shown in Fig. 55.

An evidence that the current takes extraordinarily short paths between points of entry into the body is shown by the fact that, with the active plate on the hand or lower forearm, flexing the arm will throw the preponderance of heat towards the anterior side of the flexure while extending it will cause it to pass through the olecranon; and similar shifting of heat occurs in the leg. Also, in administering autocondensation, with the patient lying or sitting on the dielectric and grasping the electrode in both hands, the current will take the shorter path from the arms across the air and clothing to the chest instead of through the shoulders; to avoid this a thick, folded towel is usually laid between the arms and chest.

Though medical diathermy is evidently the most perfect method of developing heat in deep tissues of the body, it should not be forgotten that this heat is developed in the path of the current *in direct proportion to the resistance presented by each part of the circuit.* A given current will produce more heat in bone traversed by it than in the soft, moister tissues. The skin, fortunately, presents more resistance than underlying soft tissues, and the patient's sensation at this spot becomes, therefore, an important guide to the proper limit of the current. This is of course not true if there is sensory paralysis of the skin or if the

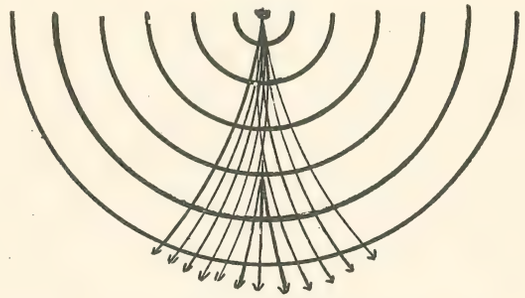


FIG. 53.—Diagram of the Flow of a High Pressure Water or Electric Current Down Curved Steps or Curved Potential Planes.

active electrode is in contact with insensitive mucous membrane. In anesthesia of the skin it is wise to avoid diathermy for fear of producing a burn.[1]

[1] N. Ernest Dorsey, Ph.D., of Washington, D. C., pointed out in a paper read before the American Electrotherapeutic Association in 1921 (*American Journal of Electrotherapeutics and Radiology,* Vol. XXXIX, p. 408) that the ammeter does not necessarily indicate the exact heating effect of the current shown by it because a portion of its indication includes a "wattless current" of no physiologic effect; and that, moreover, though it does indicate the total effective current passing through the patient, this total effective current is the product of instantaneous amperages of greatly varying amount.

For instance: in an effective or average current of 1 ampere (1000 milliamperes), shown in the meter, at 500,000 cycles per second, it was found that the instantaneous peak of amperage in each oscillation was 129 amperes (129,000 milliamperes).

If, on the other hand, the frequency be raised to 5,000,000 cycles per second, a meter reading of 1 ampere as before showed instantaneous peaks of amperage as great as 409 amperes (409,000 ma.). By another variation of oscillations an instantaneous peak of 75.5 amperes was found.

Diathermic Electrodes and Methods of Application.—In medical diathermy, which is considered alone in the present paragraphs, the sizes of the electrodes and the methods of applying them constitute one of the most important portions of the technic. Some operators employ ready-made plates of various sizes, to which the conducting wires or cords are attached by clips or soldered sockets. The author has found that these interfere with neat coaptation of the plate to the surface; not readily repairable if broken; and the heavy cords usually used with them somewhat bunglesome and too heavy, their insulation failing to prevent arcing if too near the patient or to each other.

The author cuts electrode plates of the size desired from the thick tinfoil, formerly used as an X-ray protection and com-

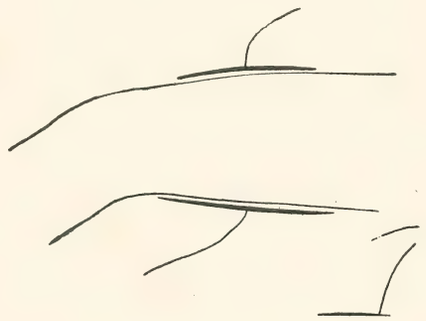


Fig. 54.—Properly Placed Diathermic Electrodes.

posed of tin and lead alloy, or from ordinary tinfoil, and attaches a piece of No. 25 double cotton covered copper wire to one corner by threading a bared end of the wire through holes pricked in the metal with a pin, and folding the corner of the plate on itself over the wire several times, as shown in the plate backing of the kaolin electrode, Fig. 16, page 21, or the wire may be attached to the back of the plates with adhesive plaster. Should these attachments break they can be repaired in a moment without resort to a mechanic.

In area the active electrode should correspond to the size of the region we wish to diathermize and the indifferent electrode should be larger. The proper strength of current to pass through an active electrode is limited by its size, as too much concentra-

tion of heat is painful and to be avoided. The following table of sizes and current strengths is quoted by Humphris as that laid down by the British War Office. It is easily remembered and somewhat lower than the limit, provided a proper contact is made with the skin:

Size of Electrodes in Inches	*Current Strength in Milliamperes*
8 in. by 4 in.	1500 to 2000
4 in. by. 2 in.	900 to 1000
2½ in. by 1½ in.	500
Circular Electrodes:	
3½ in. diameter	900 to 1000
1½ in. "	300
1 in. "	200

These dosages apply to the transverse passage of the current through a limb or part of the body. If the active electrode is on an extremity of the body and the indifferent at a distant point, we should consider the cross section of the narrowest part of the

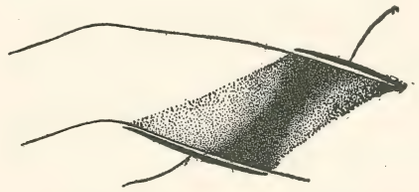


Fig. 55.—Improperly Placed Diathermic Electrodes.

limb between the two electrodes. With the wrist in circuit in this manner 500 milliamperes should be the limit, and with the ankle in circuit 700 milliamperes.

When hollow internal organs containing air are in the path of the current these figures should be reduced also, for it should be realized that the air contained in the organs will not act as a conductor but only the membranous structures; the lung tissue and the walls of the intestines.

The active electrode especially should be smooth, unwrinkled, and the edges should not make better contact than its face or blisters will result. This is easy to arrange in flat surfaces, but on curved surfaces becomes difficult, particularly if the metal is rather stiff. It is held in place by a bandage, shot bags or

sand bags. The electrodes are placed directly on the skin, though preferably moistened with a little water, as even a minute arc between the metal and dry cuticle is unpleasant. This minute arc through dry cuticle disappears after a time when the plate has not been moistened as the sweat glands beneath the plate become active. Moist pads are at times used, but are not preferred.

The patient should not be left unattended while under diathermic treatment. A sudden increase in heat due to faulty contact of the plates demands immediate opening of the power switch and readjustment of the electrode, as the sensation may quickly become unbearable. Movement of the patient may also disarrange electrodes or conductors. *When an electrode breaks contact with the skin during action a most painful arcing occurs,* even when the operator shuts off the power as soon as possbile.

It is usually best to turn on a moderate current at first, later increasing it as the circulation of the skin becomes increased and the surface of contact moist. The duration of an application should be from fifteen to thirty minutes.

Diathermic applications of a medical character may also be made with the active, metal, electrode in the vagina, rectum or other body cavities and the dispersing plate on the surface, with the same precautions in calculation of the area of the active electrode surface per unit of milliamperage as mentioned above. One must, in fact, be more particular in avoiding too great heat in the upper portions of the vagina and rectum, for the patient's sense of temperature variations in these localities is but slight, and not nearly as good a guide to toleration as is the skin or the mucocutaneous openings. For this reason the gentlest thermopenetration from a non-vacuum tube within the cavities is often to be preferred, this application being also more readily made as but one electrode is required and the patient's body need not be uncovered. It is possible, nevertheless, to apply more heat even in this manner to the insensitive parts mentioned than is wise, excessive heat causing abdominal pain for some hours after the application.

Therapeutic Effects of Medical Diathermy

Whether there are effects other than heat attending medical diathermy remains to be determined. It is possible that the chief effect at least is due to heat alone, but the special characteristics of diathermic heat being its simultaneous development throughout the path of the current between the electrodes, permitting of deep penetration, a definite dosage and ready directability to any internal organ desired, render it an important therapeutic agency for heat effects alone.

It has been known from time immemorial that the application of heat to living tissues results in hyperemia. As has been persistently urged by William Benham Snow and Frederick de Kraft, the effects of medical diathermy should be interpreted in terms of active hyperemia: a quickened arterial and capillary circulation, dilation of capillaries, effusion of serum into extravascular spaces, and stimulation of phagocytosis.

We are indebted to August Bier, of the University of Bonn,[1] for an exhaustive study of hyperemia based on older methods of heat penetration that should be reread in view of this more recent method of securing hyperemia, which in fact has been fully available only since the development of modern high frequency generators.

As elaborately shown by Bier, hyperemia has distinct *analgesic, bactericidal, absorptive, solvent* and *nutritive effects.*

The *analgesic effects of hyperemia* are most marked and have been known to all ages. This pain-lulling effect of heat, and its consequence in living tissue: active hyperemia, is limited in some cases nevertheless. For instance: the application of heat to the nerve extremities in some forms of neuritis results in increased pain, for the probable reason that the true site of the compression of the sensory neurons causing the pain is higher in the nerve trunks than the part heated, with the result of increasing the pressure on the neuron by the back pressure of an increased blood supply below the injury. This indicates the need of applying the heat directly to the pressure dam itself when this can be done, and diathermy usually makes this more nearly possible than any other thermic agency. This is at times impossible, either because of the situation of the pressure dam, as in involvement of the roots of the fifth nerve at their emergence from the cranium in tic douloureux, or because the virulence of the compression dam is increased by hyperemia, as in brachial neuralgia from compression of the subclavian nerve and vessels by a malignant growth in the subclavian region. In the latter case an action that is the reverse of hyperemia: compression of

[1] "Hyperemia as a Therapeutic Agent," by Professor August Bier, translated by Dr. Gustavus M. Blech, A. Robertson & Co., Chicago, 1905.

the hand and arm by a bandage, gives greater relief. Diathermy, or any other measure favoring hyperemia, applied to the arm below the compression will inevitably increase the pain.

When hyperemia is induced directly within the neuron pressure region in benign conditions relief of pain is almost certain, doubtless due to the physical alterations of the part for the better described below.

The *bactericidal effect of active hyperemia* is also an effect which has been recognized by both physicians and laymen from olden time, though its true explanation was not known before the revelation of the bacterial nature of inflammation. This was the application of heat in the shape of poultices to abscesses, etc. As now interpreted, active hyperemia is a reparative process in inflammation, acting by increasing the flow of blood in the capillaries and partially arresting it therein; producing at the same time a transudation of the defensive serum and phagocytes into the tissues outside the capillaries, and thus aiding in the attack on the bacteria in the lymph spaces, where they are said to be most numerous.

As a necessary sequence to these facts it may be predicted that diathermic hyperemia will be found to be useful in the *acute, grave bacterial infections of internal organs, such as pneumonia, peritonitis, etc., when the internists perfect the technic and indications.* Some favorable reports have been made by electrotherapeutists in these conditions, but full establishment of the indications and contra-indications must await hospital research by the internist.

It should not be forgotten in this connection that the application of cold in grave acute bacterial invasions has been demonstrated to be merely another way of obtaining active hyperemia in the parts situated a short distance beyond the chilled area, and that a deeper hyperemia, if that is desired and useful, and one that is absolutely under control of the physician as to location and degree, is possible from diathermic applications that can be made at the bedside in the hospital by employing large movable generators.

With the effects of diathermic hyperemia on chronic bacterial foci, as the arthroses, chronic inflammation, etc., we have a large and increasing experience of a favorable character, though here the interpretation of the results obtained is somewhat confused by a similar effect of the hyperemia as an analgesic, absorptive, solvent and nutritive agency.

The *absorptive effect of hyperemia* is in full accord with our modern scientific knowledge that the channels of absorption of water are mainly in the blood vessels, quickened activities in which can only cause greater absorption of water and bodies soluble in water. This renders diathermic hyperemia a most valuable agent for recent effusions of blood after bruises and injuries of any character, or the more delicate vacuum thermopenetration for effusions within the orbit. It also explains the value of diathermy in causing absorption of watery exudates, and exudates soluble in water, that have remained in the lymph spaces long enough to have become chronic.

The *solvent effect of hyperemia* is most notable when joints with arthritic concretions are subjected to diathermic hyperemia, provided the deposits are relatively fresh. Here the hyperemia causes the nodules to be dissolved in the blood plasm before absorption. Whether this solution and removal of the exudation is by hyperemic increase of chemical action or hyperemic increase of phagocytosis remains uncertain

AUTOCONDENSATION

This term is applied to that modality of high frequency applications in which the patient forms one side of a condenser (page 81), this particular condenser consisting of a silk cushion dielectric or a fiber dielectric on which the patient reclines or sits, the fiber or cushion taking the place of the glass in the standard condenser; and the patient, grasping a cylindric metal electrode, constitutes one coating of the condenser, analogous to one of the tinfoil sheets, while the other coating is a metal plate beneath the dielectric. The patient is connected with one pole of the Tesla or d'Arsonval circuit by a conductor attached to the hand electrode, and the plate beneath the dielectric is connected with the opposite pole, after passing through the meter (Fig. 56).

With the patient in position (the power switch open, the selector pointing to the current desired, the controller switch on the first or a higher stud, and the spark gap closed), one conductor is attached to the plate beneath the dielectric, with the hot wire meter in circuit, and the other conductor to the hand electrode held in the patient's hands. It is well at this point to place a thick, folded dry turkish towel beneath the arms of the patient and below the hands and electrode if lying down, to divert the

current through the patient's shoulders. The power is now turned on by closing the power switch, and the spark gap is opened gradually to avoid sudden heat sensations in the wrists. If the full gap is not sufficient to give the current desired, additional power is added by placing the controller switch on a higher stud.[1]

Referring to the description of condenser action on page 81 it will be seen that this arrangement is, in effect, that of the condenser within the generator cabinet charging a condenser outside, of which the patient's body forms a part, through the oscillation transformer; and as the condenser discharge resides in

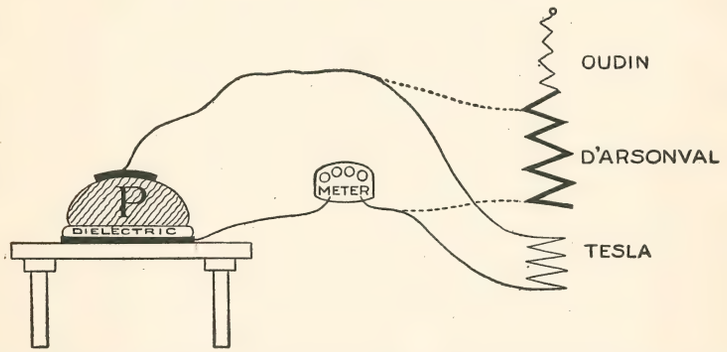


FIG. 56.—Connections for Autocondensation. Either the d'Arsonval or the Tesla current may be used.

the dielectric, the silk or fiber cushion, the current indicated by the hot-wire meter does actually traverse the body as its port of entry to and from the dielectric, the charge heaping up most probably in the portion of the body nearest the dielectric.

The first feeling of the patient is that of warmth in the wrists and arms, followed later by a pleasing warmth of the whole body, a lowering of nervous tension and of the blood pressure if either or both are higher than normal.

Some operators prefer the d'Arsonval current and others the bipolar Tesla for autocondensation, in each case the hot wire meter being included in the circuit. More current volume can

[1] Increased milliamperage and heat are often best obtained in diathermy and autocondensation by increasing the current at the resistance switch instead of at the spark gap. As the spark gap is increased, one must usually cut out resistance also to obtain proper resonance.

be applied from the Tesla circuit usually though not with all types of generators, as indicated by the meter, and that its voltage is greater than the d'Arsonval is shown by the greater distance from the patient that a vacuum tube, held in the operator's hand, is lighted up while the treatment is being given.

The physiologic effects of autocondensation differ so greatly from those attending a similar volume of high frequency current applied by simple diathermy that we have in it a different physiologic and therapeutic agency. The chief physiologic difference is, that while diathermy raises the blood pressure, autocondensation lowers it.

The dosage of autocondensation varies from 350 milliamperes to 700 milliamperes according to the case and the effect secured, the duration of the application being from twelve to twenty minutes. At the completion of the application the current is turned off by reversing the steps for turning it on given above, and the after treatment blood pressure record is made.

In a patient presenting high blood pressure, or even with an habitual nervous erethism, the result of the treatment is calming and refreshing, and the pressure may decline temporarily five to ten millimeters of mercury. The repeated use of the method tends to a somewhat permanent improvement, provided measures are taken to remove intestinal toxemia, so often a causative factor in these cases. Under the use of these combined measures a restoration to health is at times possible, moderate amounts of albuminuria even being lessened or removed entirely.

Autocondensation should not be employed in debilitated conditions with lowered blood pressure, being at times dangerous to such patients, and should be used with care in old people.

Autoconduction.—Little is known practically of autoconduction in America, though it has been used when produced by the static generator by some operators, notably the late Dr. Francis B. Bishop, of Washington, D. C. The following account of this modality as employed in England is taken from Chisholm Williams:

"The noteworthy feature of this method is that the patient is not in actual metallic contact with the solenoid. The solenoid is made like a cage, and large enough to envelop the patient, who either stands up inside it, or lies on a couch placed within it. Smaller cages may be used for arm, leg, etc.

"The passage of the current through the cage induces by mutual induction high frequency currents in the tissues of the

patient, which may be demonstrated by sparks being drawn from any part of him—that is to say, he is saturated by being placed in the field of the currents.

"If a lamp of 20 volts be used to close the circuit of a single coil of thick wire, it illuminates with a brilliant light at a distance of more than 3 feet. Any conducting body plunged into this field becomes influenced with induced currents.

"If a single copper wire of one turn is introduced, the induction produced in this wire will be sufficient to light up two lamps of 110 volts mounted in series. Place the patient in the large solenoid, and let him unite his arms in such a way as to form a circuit which is completed by an incandescent lamp, the terminals of which communicate with each hand. The lamp is lighted with this induced current in the circuit thus formed. Another more certain method is to plunge each hand into a vessel containing a slightly alkaline solution of hydrochlorate of ammonia. Under these conditions the absorption by the skin makes the resistance fall to the extent of 600 ohms. As it is known that the electromotive force induced from a single coil can easily attain 100 volts, one can say that the intensity of the current which emanates from the arms may approximately reach $\frac{100}{600} = 160$ milliamperes.

"Apostoli and Berlioz have described another modification, the patient being placed as above, and connected by the hands with one pole of the solenoid. Under these conditions the patient is treated by direct and autoconduction, the effects of both being thereby increased.

"The effects seem to be much like autocondensation, and it is chiefly used in treating general conditions, such as rheumatism, anemia, chlorosis, and certain forms of diabetes. One sometimes gets better effects from changing from one form of treatment to another.

"As yet no hard-and-fast rule can be adopted; everything must be left to the discretion and experience of the medical man." [1]

It is evident from this account that the current supplying this cage was derived from the Oudin circuit, though Mr. Williams does not say so. The modification of Apostoli and Berlioz evidently employed the Tesla or d'Arsonval circuit, the connections being bipolar, or one pole to each end of the cage. The use

[1] "High Frequency Currents in the Treatment of Some Diseases," by Chisholm Williams, F.R.C.S., Rebman Co., New York, 1903.

of the static current to charge the cage would resemble the same use of the Oudin circuit—that is, be unipolar, with effects more nearly resembling effluvation.

Effluvation.—The effluve, taken from the Oudin resonator of a high frequency generator and applied to the patient by a many-pointed electrode mounted on an insulating handle, is used abroad for conditions for which the static breeze, static spray and pencil discharge from powerful static machines is employed in this country. The superior construction of American static generators has resulted in little or no use of the effluve from high frequency generators in this country as the static brush discharge is greatly superior. The therapeutic indications are those of "derivation," counter irritation and surface stimulation.

SURGICAL HIGH FREQUENCY MODALITIES

DESICCATION; HIGH FREQUENCY CAUTERIZATION; ELECTRO-COAGULATION

The differences between medical electrothermy and surgical electrothermy with high frequency currents is that of the degree of heat developed in a given area of the tissues, the purpose of the medical heat being to produce a remedial hyperemia, while the surgical use is for the destruction of life in the part. The difference therefore is not merely that of current volume, but of the *concentration of the volume of current at the spot of application.* To illustrate: a fine spray of the Oudin current concentrated at the point of a very sharp needle and directed at the skin surface will desiccate quickly, though the current volume be far too small to be indicated on any meter employed for measuring high frequency currents, while as much as 2,000 milliamperes may be applied by large plates to the same surfaces with only a moderate reddening effect on the skin, accompanied by a sensation of comfort.

Further analyzing the two illustrations will bring out another fact. If, instead of raising the point applying the Oudin current to the skin to form a minute arc we allow the point to rest on the skin, less destructive effect will accompany this application of a weak Oudin current. The reason is that, with the point resting *on* the skin the minute current becomes a diathermic application, with too little amperage to heat perceptibly; when it is raised to permit the current flow to become

an arc through the air, *the heat potential is concentrated on the surface itself,* with visible and sensory effects.

Electrodesiccation.—Surgical high frequency electrothermic methods are thus divided into two widely differing modalities: those that *concentrate the heat on the surface* by means of an arc of electrons passing from metal to tissue through air or other fluid; and those that *develop the heat within the tissue* by reason of a *moist contact* between metal and tissue that blots out all air layers. The methods that include the arc in the

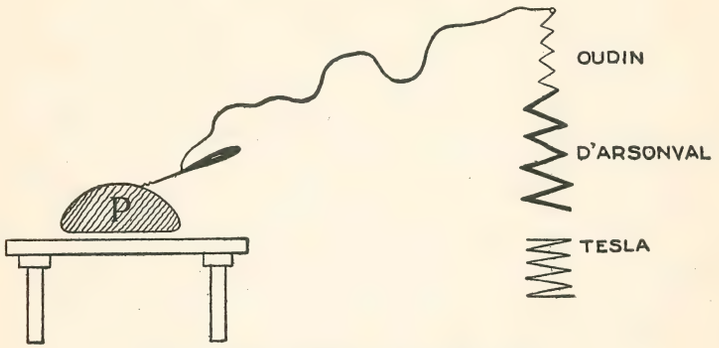


Fig. 57.—Electrodesiccation Connection.

circuit are known as *electrodesiccation* and *high frequency cauterization.* That in which no arc should occur between metal and tissue is known as *electrocoagulation.*

Electrodesiccation, the "hook up" of which is shown in Fig. 57, employs the weakest Oudin current, which is rendered effective by concentrating its powers at the point of a very fine needle or sharpened wire, and the air arc need not be more than several millimeters long or even one millimeter at a sensitive spot. It is unipolar, and of invaluable service in the quick, almost painless destruction of small surface neoplasms; in sterilizing diseased follicles in tonsils, etc. The devitalization of the surface by desiccation is so delicate that the tissue appears whitened rather than carbonized, hence the designation. The technic of desiccation applications and of other surgical electrothermic methods is given in the Chapter on Oncology, page 192.

High Frequency Cauterization.[1] — Desiccation may be

[1] The word "fulguration" should be discarded as meaningless from present day high frequency surgery. It was originally applied to the Rivière and deKeating Hart treatments of cancer with long effluves or long sparks of indefinite constitution, being intended in the latter operator's method as a mode of "inhibiting" the remaining cancer cells in the wound after an incomplete excision operation for its removal. The meaning of the word has become so indefinite of late as to rob it of descriptive value,

changed into cauterization by merely increasing the power of the Oudin application in desiccation, but a hotter arc is obtained from the unipolar Tesla terminal (Fig. 58). With increased heat there is increased action, pain, and finally carbonization of the surface. This "hot spark" is employed for surface growths only, with local anesthesia, as its penetration is not great, due to expenditure of potential on the surface and the greater resistance to current flow presented by a charred surface. It is employed unipolar only.

Electrocoagulation.—This modality is a true application of diathermy to surgery, in which, *by the elimination of arcs* be-

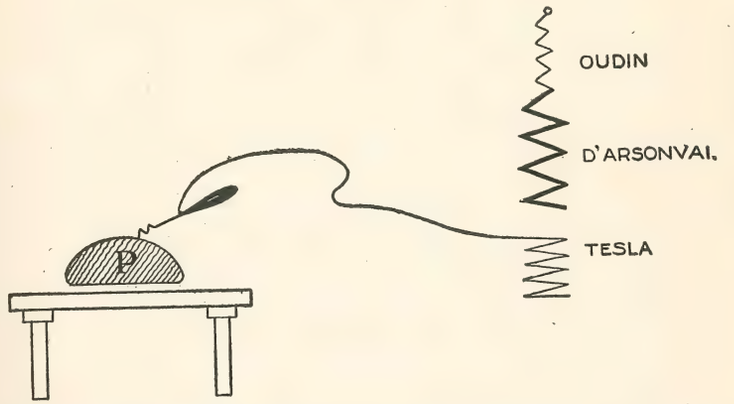


Fig. 58.—High Frequency Cauterization, or "Hot Spark" Connection.

tween the metal conductors and the tissue surfaces, *the resistance of the tumor tissues is kept down to an ohmage through which the voltage of the d'Arsonval current can drive enough amperage through the tumor tissues to raise the temperature to the boiling point quickly.* Since moist living tissue is a fairly good conductor, its slight resistance (from which heat is derived, page 58) demands very large amperages in this modality to produce adequate heat.

This modality employs a metered d'Arsonval current (Fig. 59) and is always bipolar, that is: both poles are in direct con-

tact with the patient, though two dispositions of the poles are made, the usual one being one pole as an active electrode in the neoplasm and the other as a dispersing electrode on a distant skin surface; while the other arrangement, only possible with high frequency currents when the growth is large, is with both poles within the growth, a large growth permitting the opposite electrodes to be far enough apart to eliminate arcs between them or the conducting cords.

It is only necessary to produce sufficient heat in surgical diathermy to coagulate protoplasm to destroy it and all intercellular or endocellular living germs in close association, hence the value of the method in the destruction of tissue infected with any form of germ life, in which incision methods are liable

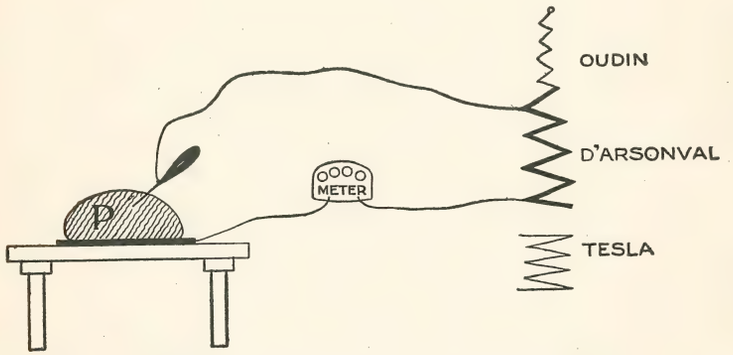


FIG. 59.—High Frequency Electrocoagulation Connections.

to reinfect the exposed edges of an incised wound. Like electrocoagulation with the direct current, it seals lymphatic spaces and channels and small blood vessels, and fuses nerve conductors into a condition in which pain conduction is impossible. The arrangement of polar contacts into active electrode and dispersing plate (called the unipolar method in direct current electrocoagulation, but a form of the bipolar method in high frequency surgery) is a very convenient method for the destruction of growths within cavities, and possesses overwhelming advantages over a similar arrangement of direct current electrodes in *eliminating all nerve and muscle response in tissues beyond the growth,* that has limited the value of the direct current method in cavities unless it could be strictly bipolar. But, when the true bipolar direct current method is possible (both

poles within the tumor), no such disadvantages attend the bipolar direct current method, for but little current strays beyond the peripheries of the growth in this form of bipolar direct current application, and the many advantages that attend the handling of low voltage electrodes freely, even uninsulated, such as close placement of opposite poles in the tissue without sparking, absence of danger from ether fumes, and addition of zinc ions to the heat devitalization, all render the direct current more convenient when similar amperages are used.

The details of high frequency electrocoagulation operations are given in Chapter XII.

CHAPTER IX

STATIC ELECTRICITY

Mode of Production—Charging the Static Generator—Polarity of Static Currents—Care of the Static Generator—The Grounds in Static Modalities—Static Wave Current—Static Sparks—Static Brush Effluve—Static Vacuum Tube Current—Static Bath—Static Induced Current.

Static electricity differs so greatly from other electric currents that the armament of a physician, if not the surgeon, is incomplete without it. In its qualities it resembles the atmospheric electricity of thunder storms, as was shown by Benjamin Franklin in his historic experiment with the kite, though the phenomena produced by the static generator of the physician is on an infinitely smaller scale. It was used by Franklin in some medical applications. It was reintroduced into medicine in this country by the late William James Morton, son of the discoverer of anesthesia, and has been greatly developed by William Benham Snow, Frederick de Kraft, and Edward C. Titus of New York and F. Howard Humphris of London.

The static generator is, in effect, a dynamo in which the field magnet is the paper element on the stationary plates and the armatures the shellacked plates that revolve before them, and it is interesting to note that it was developed into almost the present form of the Holtz machine in Europe long before the development of the modern dynamo of iron magnets and wires in America.

Like the D C dynamo, the static generator is a device for multiplying an initial charge of electrons by repeated self-inductions, until, in a suitably insulated circuit, *a small charge of electrons on the field elements is raised to an exceedingly high pressure,* amounting to hundreds of thousands of volts, while the conditions attending the creation of this high pressure—mainly the air gaps it has to traverse within the generator—preclude the production of much volume, the amperage being but the fraction of a milliampere in the current from the most powerful generator.

Since air forms a portion of the circuit within the generator and also acts as an insulator, this high voltage makes it necessary that the air within the generator be kept exceedingly pure and dry.

The action of the static generator is as follows: An initial charge on one of the paper field elements induces a charge of opposite sign on the surface of the revolving plate before it; this charge is carried by the revolving plate and internal circuit

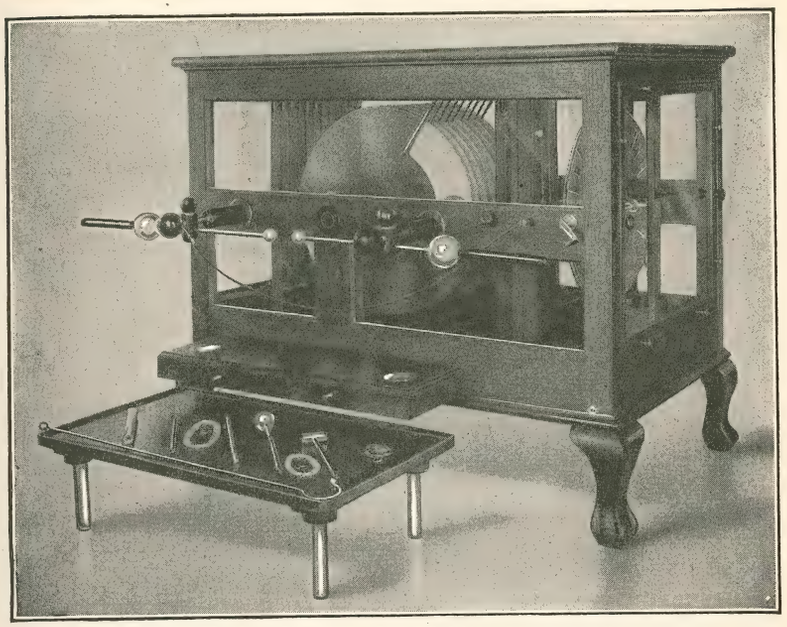


FIG. 60.—Holtz Type of Static Generator, Insulating Platform and Electrodes.

of combs to the second field element in such a manner that this element receives an opposite charge; repeated revolutions of the armature plate result in geometric multiplication of the initial charge by induction; until in a few moments a current of very high voltage may be collected from the opposite sides of the revolving plates and conducted to the discharging rods, where the air resistance finally breaks down and a series of sparks flows between the discharging rods of the spark gap.

The current thus produced by the static generator is a current of electrons flowing from the cathode or negative pole only. It is therefore a direct current in every respect, but as it differs so greatly from the low volt direct current it is usually designated as unidirectional. This unidirectional character of the static current makes it entirely different from the Oudin current of high frequency generators, which are alternating.

The pressure or voltage of the current from a static generator is determined by the diameter of the revolving plate, plus the speed of revolution; while its amperage is determined by the number of revolving plates, plus the speed of revolution. As a very great speed of revolution is often undesirable in a treatment room the present consensus of opinion favors a large revolving plate, of which there should be at least sixteen, with the necessary stationary plates, and a moderate speed of revolution.

The Holtz type of generator (Fig. 60), which is indicated by the presence of a window, or open space, in the stationary plates next to the field elements, is generally preferred as less liable to change polarity over night or during operation, as happens at times in some makes, though it has the disadvantage of not being self-charging as the Wimshurst and Toepler-Holtz usually are.[1] This is overcome by the placing of a small Wimshurst generator in the same case for hand operation to charge the larger generator while in motion, the charging unit being disconnected by an external lever as soon as the larger unit begins to produce current. The power is derived from an electric or other motor placed on the floor and transmitted to the generator by belting.

The motor operating the static generator should have several speeds, as it is unwise to throw the revolving plates too suddenly into the highest speed. With the discharging rods a short distance apart, power is gradually turned on.

The strength of the current administered to a patient increases directly with the length of the spark.

Charging the Static Generator.—With the discharging rods a short distance apart, power is gradually turned on the motor, and if no current appears at the spark gap the Wimshurst

[1] For descriptions of the Wimshurst and Toepler-Holtz types of generators see textbooks on electricity and magnetism. See also an excellent monograph "Static Electricity," by William Benham Snow, Scientific Authors' Publishing Co., New York.

generator in a Holtz apparatus is connected by the lever and is vigorously operated by hand for a few moments, the connecting lever being turned back as soon as the main generator is charged, the latter being left in operation in the meantime.

If no current appears at the spark gap after a few minutes' operation, and the case enclosing the generator is clean and dry inside and out, an initial charge may be conveniently given from an X-ray transformer delivering a rectified current by the following connections:

With the transformer spark gap set at four or five inches, disconnect the X-ray tube from the transformer and connect one pole of the latter with one pole of the static generator by a sufficient length of wire or conducting cord that is carefully insulated from metals or possible contact with the operator. With moderate power on the static generator, close the main switch of the X-ray generator for a moment every few seconds. When the static generator is seen to operate, disconnect the wire by means of a vulcanite or glass rod and then turn the X-ray generator off.

Polarity of the Static Current.—The direction of the flow of electrons between the balls of the spark gap, or through the air, patient and other substances placed in this circuit, is determined by the accident of which field element has a predominant charge when the generator begins to operate; it is necessary, therefore, to determine the polarity each time that a Holtz generator is freshly charged, and every time a Toepler-Holtz is used, as this current is always unidirectional and its polarity is an important detail in therapeutic work.

If the spark gap balls are clean and free from deposits of synthetic combinations of the oxygen and nitrogen of the air, due to previous action of the generator, the polarity may be evident at a glance when the generator is in moderate operation through a gap of about an inch and a half: the stream of electrified air particles shows a bright white color next the anode or positive pole and a purplish blue next the cathode—probably due to the white color of ionized and incandescent oxygen at the anode and the bluish color of ionized nitrogen at the cathode.

Any doubt as to polarity may be absolutely dispelled by the following simple test: On a large piece of glass supported in front of the spark gap place two pieces of wet litmus with their approximate ends in contact to make the strip long enough; beneath each end of the strip place the end of a fine wire, the

wires being carried to each side of the spark gap and connected with the discharge rods by winding them about them. Such an arrangement of the circuit will permit of a conductive discharge of the current from the poles through the wet litmus paper. If now the generator be operated vigorously a blue stain will appear very quickly in the litmus paper in contact with one wire. This can be only the cathode, for the anode produces an acid reaction. The discharging rod connected by wire to the blue discoloration is therefore the cathode.

Care of the Static Generator.—In spite of the fact that static electricity is difficult to generate or use in very humid air, by reason of the facts that dry air is an essential portion of the circuit within the generator, and equally essential as an insulating medium for the current produced both within and outside the generator, the American types of static generator are capable of being operated successfully in any climate. This is due to their enclosure in a case that is made as air tight as possible.

One of the characteristics of static currents resulting from their unidirectional character is their power to ionize the air they pass through. This results in the formation of nitrous acid as well as in much free ozone. The presence of this ionized air is evident to the senses after a thunder storm; and the same facts are at the basis of the production of artificial nitrite compounds for commercial purposes. With the large number of revolving plates in a modern generator its operation for any considerable time results in the formation of much of these products, which in time are deposited as a hygroscopic film on the walls of the generator and on its operating parts. The result is impairment of inductive and insulating capacity and lessened generating power of the apparatus.

This unfortunate result is best prevented by the use of unslacked lime (calcium oxid) in lumps in the case, as first suggested by Snow, the lime absorbing the products of ionization from the action of the generator as they are produced, as well as keeping the generator dry. Dr. Snow advises the enclosure of the quicklime in a box made of slats, which is but partly filled with the lime on account of the expansion of the lime as it slacks, the box being covered with two thicknesses of fine muslin to prevent distribution of the fine lime powder over the generating plates. The author varies this slightly by placing the lumps of lime in the center of a yard of four thicknesses of surgical gauze and folding the gauze lightly over the lime,

the gauze stretching as slacking occurs while continuing to cover the slackened powder. A similar package is placed in either end of the case, resting on its floor. The lime should be renewed whenever it appears to have become slacked, which will be several times a year in average use. A pan of anhydrous chlorid of calcium may be added for additional water absorption if the climate is moist, this panful being capable of indefinite renewal by being dehydrated on a gas stove whenever the case is opened for any purpose, *but this substance will not absorb the nitrites produced by ionization in the case without the assistance of oxid of lime,* and the condition of the generator when it has been used alone has given rise to the unfounded belief that it is directly responsible for a gummy condition of the generating surfaces. Its use will save the quicklime for a more prolonged use.

A clear dry day, with low humidity, should be selected to open the case during the summer months. This is preferably several days after a copious rainfall.

The outside of the generator should be kept as clean as the inside, and proper attention be given to keeping the bearings oiled.

The spark gap should be left well opened by separating the balls at the end of each application. This lessens the liability of the generator losing its charge between applications, *but no treatment should be begun with the patient in position without considering whether the treatment is to be given with the spark gap closed or open,* as failure to note this point will give unpleasant shocks in certain of the modalities. No conducting cords, wires or electrodes should be left attached to the generator when not in use.

If a generator has become foul within by reason of neglect of the use of quicklime, or its too infrequent renewal, it may cleaned with a cloth moistened with gasoline, but the case must be freed from gasoline vapor before the generator is operated for fear of an explosion. Kerosene has also been used for this purpose.

The Grounds in Static Modalities.—A proper "grounding" is as important in some static modalities as it is in radio receiving, yet this is often imperfectly accomplished. Two "grounds" are needed, in fact, for the application of indirect sparks, while one is sufficient for the static wave current.

Ground wire connections need not be soldered, as is essential

in radio because of the minute current quantities to be detected in the latter, but they must reach the moist subsoil or large masses of metal in contact with moist earth. The fact that two grounds are needed in indirect sparks means simply that a condenser action (page 81) is essential to this application, being in this case achieved by *two masses of metal separated by ordinary earth.* A water pipe forms an excellent terminus for one ground attachment, as any insulating joints are cut out by the excellent conducting medium within the pipe, but a gas filled pipe with similar joints is poorer, even when bonded in the basement with other pipes.

The general practice of bonding all conductors in the basements of houses supplied with electricity makes it impossible to use these pipes for more than one ground. A lightning rod, in contact with moist earth, is the best second ground. In its absence the copper rain spout connected with the soil pipe, or the soil pipe itself, in an apartment house or office building may be used with the ground wire securely wrapped about it many times; or if this is impracticable, a piece of galvanized iron pipe may be driven into contact with moist earth outside the house and its upper end wrapped about with the ground connection wire. The best ground should be connected by means of the leading-in wire with two binding posts or simple hooks on the wash-board or wall a yard beyond each end of the generator, so that either of the prime conductors or poles may be grounded at will, as anode or cathode, according to the occasional shiftings of polarity in some generators. The other ground leads to a single terminal post on the wall back of the place where the operator stands when administering indirect sparks.

STATIC MODALITIES

Static Wave Current.—For this the patient sits or reclines in a chair placed on the glass insulated platform; a thin metal plate, such as is used for high frequency applications, but only as large as needed to cover the part to be treated, is moistened and held by a bandage or otherwise in contact with the skin or mucous membrane, and connected by a light wire with the anode of the generator and the cathode is grounded. Dr. Snow, to whom we owe mainly the use of this modality, commends the memorizing of this polar arrangement by recalling the initial letters P. P. (positive—patient).

With the spark gap closed, the current is turned on at the motor and the spark gap opened slowly to a point within the comfortable endurance of the patient, and until a local effect is experienced under the plate in addition to the general thrill as each spark passes in A circuit at the spark gap. The application should continue twenty minutes to half an hour, *and be terminated by closing the spark gap before the generator ceases to act or the electrode is removed.*

The physical action on the patient is that of a charge and discharge in a B, or shunt circuit as each spark flows between

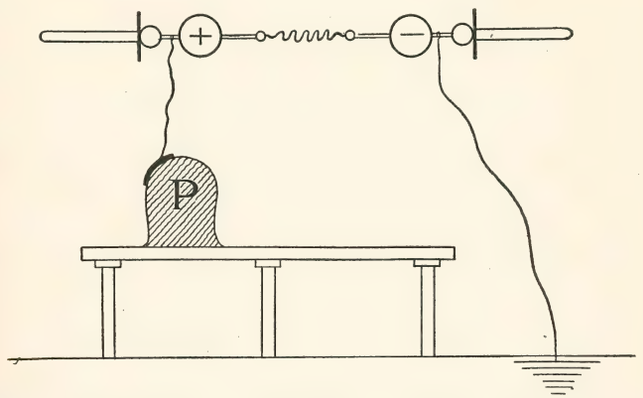


Fig. 61.—Connections for Non-Rhythmic Static Wave Current.

the terminals in circuit A. As the patient is in circuit B and insulated and connected with but one pole, it appears at first sight that no current would traverse his body but only a charge and discharge synchronous with the sparks. The patient appears to be in the position of a bird resting on a bare telegraph wire, but with the great difference that the telegraphic impulses are of such low voltage that the bird receives no charge evident to the senses. Owing to the enormously higher voltages of the static current the charge and discharge received by the tissues of the patient are capable of producing a deep action on contractile tissues.

But another physical condition present in the static wave greatly intensifies the charge and discharge. With the opposite pole well grounded, a condenser effect (page 81) is produced, one side of the condenser being the patient's tissues and the

other the charged walls and floor of the room, with the intervening air as dielectric. Removing the ground temporarily will show that this condenser effect is an essential part of the "hook up" as but little current will then reach the patient. There is some similarity in the electrophysics of this application and that of autocondensation (page 111), with the enormous differences

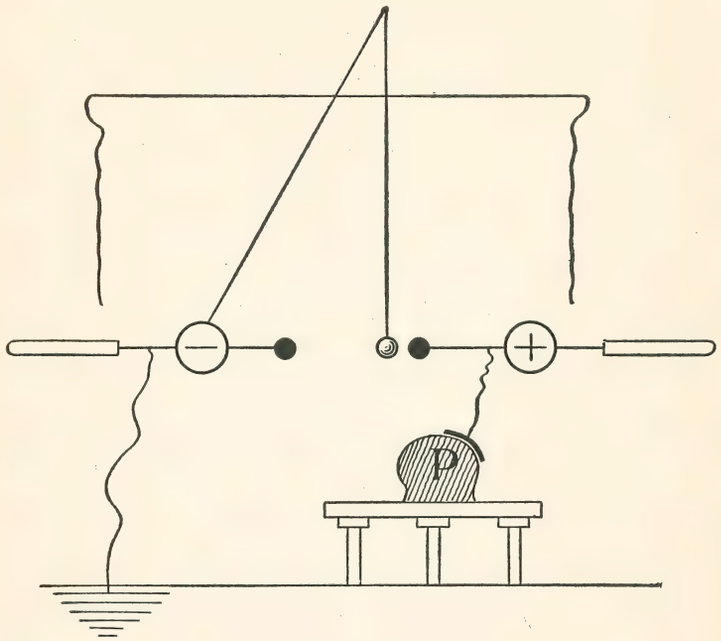


FIG. 62.—Turrell's Connections for Rhythmic Static Waves. The suspended ball replaces the negative ball. It must be light in weight and metallic. The suspending wire is No. 28 or 30 copper.

that the static wave is unidirectional, and of so slow a frequency that the wave action on contractile tissue is its most important function.

It should not be forgotten that the amperage of the static wave increases with addition of condenser capacity in the shape of metal masses connected with the circuit. Some operators increase the amperage by placing a Leyden jar in the circuit between the negative discharging rod and the ground.

The static wave current as thus described is not rhythmic,

and is for this reason less useful in stimulating the external muscles as described in the chapter on Wave Currents. Several devices have been arranged to make this current truly rhythmic, the most simple being that of Major Turrell, described as follows by Humphris:

"From the negative discharging rod a wire is led to an insulating rod projecting from the top of the case of the static machine, and so placed as to be immediately over the positive discharging ball when half withdrawn; from the projecting end of this rod a fine wire, connected with the wire previously mentioned, drops vertically downwards, and to its lower end a metal disc is attached so that its edge rests lightly against the positive discharging rod or ball. The discharging rods are then withdrawn about half their full extent; no sparks will pass as the current is short-circuited by the wire and disc. With the machine in operation the disc is given a slight tap with a non-conducting stick; the disc then commences to swing, and a rhythmical swing will then be maintained automatically by the alternate attraction and repulsion of the electrical charge. As the disc swings away from the rod a stream of sparks will pass from the negatively charged disc to the positively charged rod. When the disc is in contact with the rod the patient's charge will be at zero, and it will be at its maximum when the disc is farthest from the positive rod."[1] Figure 62 shows this valuable "hook-up" with a ball on the end of the pendulum wire.

Dr. J. Willard Travell, of New York, has also devised a hook up shown in Fig. 61 for rhythmic variation of the static wave current, which he demonstrated at a recent meeting of the American Electrotherapeutic Association.[2] It is likely that this arrangement would produce greater amperage than that of Turrell since it includes a condenser in the hook up.[3]

Therapeutic Indications.—The physiologic action of the static wave current is that of a local decongestant by reason of its contraction of the vasomotor muscles, and the indications for its use point to great value in surgical accidents, such as sprains and ruptures of ligaments, the convalescence from injuries of this character being greatly shortened by its use. In these con-

[1] "Electrotherapeutics for Practitioners," by F. Howard Humphris, London, 1921, Henry Frowde, Hodder and Stoughton, pp. 41, 42.

[2] *American Journal of Electrotherapeutics and Radiology,* January, 1923.

[3] Dr. Victor C. Pedersen exhibited a musician's metronome as a rhythmic agent at a recent meeting of the American Electrotherapeutic Association. The metronome is inserted into the circuit in place of the Leyden jar shown in Fig. 63.

ditions, and in the chronic inflammatory conditions encountered by the gynecologist and proctologist, the only question lies in the relative importance of this modality and diathermy. In some cases this is best decided by the employment of both modalities at the same séance, the diathermy being used first as a preparation for the tissues.

The fact that the static wave current will relieve pain of noninflammatory origin also when applied to the overlying skin makes it of value in neurology, as well as the fact that it exerts an influence in increasing perspiration during the séance, and allaying nervous erethism.

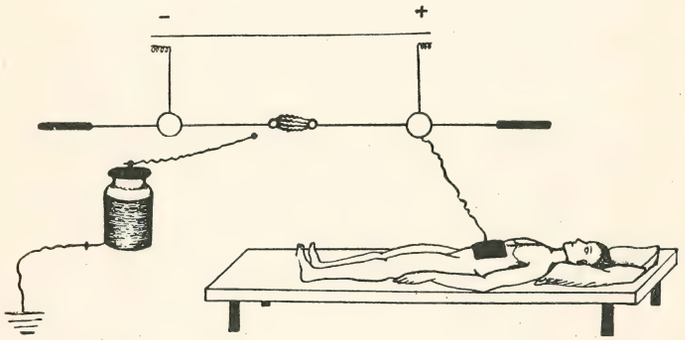


Fig. 63.—Travell's Connections for Rhythmic Static Waves. A thin brass strip ending in a light brass ball is attached to the Leyden jar. The ball is attracted to the discharging rod at intervals.

Static Sparks.—The direct static spark, with the patient on the insulated platform connected directly with one pole of the generator, while the spark is administered from a ball electrode connected directly with the other pole, is too painful for use, particularly with the powerful American generator. It differs physically, moreover, from the indirect spark (which is the static spark alluded to elsewhere in this work and the one usually employed) in being more of a discontinuous, high voltage arc applied to the surface of the body than the separate capacity discharges into the subdermic tissues that are the physical characteristics of the indirect spark.

The indirect spark is administered as follows (Fig. 64): The discharging rods of the spark gap are separated; the positive pole or anode is connected to the ground wire leading to moist earth; the patient stands on the platform at one end of a grass-

cloth rug or several thicknesses of paper placed on the platform, at the other end of which the rod from the negative pole of the generator rests—preferably on a moistened spot of the rug or paper; the ball electrode to be handled by the physician is connected by a chain or wire with another "ground" (a gas or water pipe if the regular ground is not also connected with it) and the motor is started slowly. With the spark gap not too wide, the ball electrode is approached to the part to be treated by a throwing motion, calculated to deliver but one spark to each motion. If the electrode is not thus drawn back at once a second or more sparks will pass to the patient, complicating the effect and adding to the pain. Dr. Snow, in order to reach

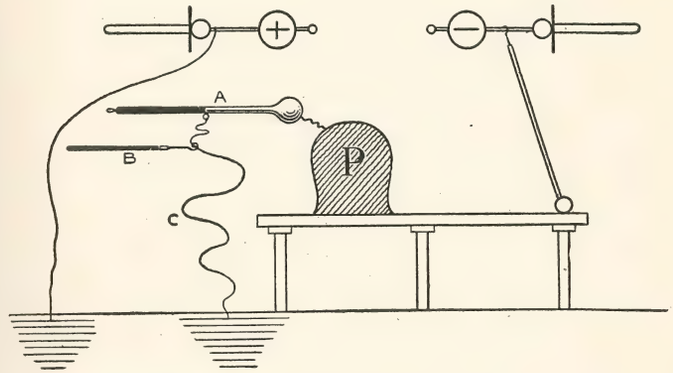


Fig. 64.—Connections for Indirect Static Sparks.

curved spots on the body surface, places a directing electrode on the spot desired and applies the sparks to this second electrode, from which it is conveyed to the patient.

The strength of the spark is governed by the speed of the generator; by setting the spark gap to waste all over a desired length of spark; by a field-controlling device within the generator; or by the patient moving on the rug covering the platform to place more or less of the rug between her and the conducting rod.

The action of the dielectric earth between the two metal grounds is to change the arc of direct sparks into individual impulses of more volume and deeper penetration.

Static sparks may be given as well through the clothing as to the bare skin, provided the clothing is quite dry. The most

perfect sparks are applied through dry clothing, the outer surface of which is an even textured wool, but corsets or other metallic substances must be removed or else the metal will carry the currents to spots not aimed at. *Celluloid articles should be specially removed as there is grave danger of their becoming ignited.*

The duration of an application of static sparks is but a few minutes, the motor switch being opened as soon as the treatment is ended.

Therapeutic Indications.—The application of static sparks is invaluable in the treatment of hysteria, particularly of those types presenting anesthesias of various portions of the surface. No other modality can take its place. The *modus operandi* is probably by an efferent excitation of the disordered sensory

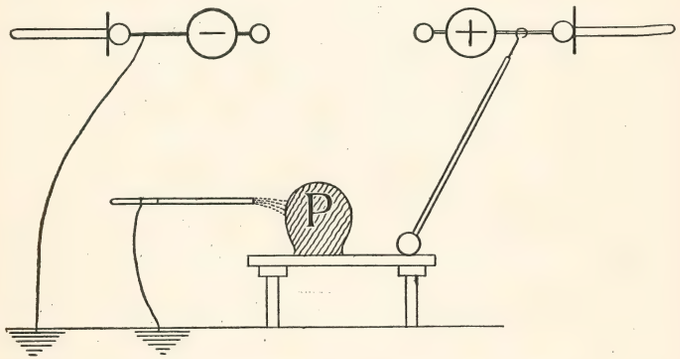


FIG. 65.—Connections for Static Brush Effluve.

neurons. Some hysterical patients actually seem to enjoy shocks of this nature that are very painful to a normal individual, and unendurable to a patient suffering from neurasthenia. The static spark application becomes therefore a valuable agent in the differential diagnosis of hysteria and neurasthenia (page 393).

Sensory palsies of organic nature, such as are found in sciatica, locomotor ataxia and paraplegia are greatly benefited by this modality.

Static Brush Effluve.—The static wave is *conducted* to the patient by a metal conductor. The sparks modality just described is an irregular charge of electricity that reaches the patient by *disrupting the air.* If, instead of this charge being held back by globular poles at the spark gap and at the electrode presented to the patient, it is sent through the air from many

fine points, we have a *convective* discharge of this very high voltage current through air, in many ways similar to the discharge of a low volt current through an electrolyte, save that, air not being a compound but a mixture of molecules, the result is ionization and synthesis, the resulting products, together with the merely charged air, conveying the current between the poles or pole and patient by convection.

Ozone and nitrous oxide will appear in great abundance at the surface of the positive pole, or at the skin of the patient if he be connected with the positive pole, while the negative polar

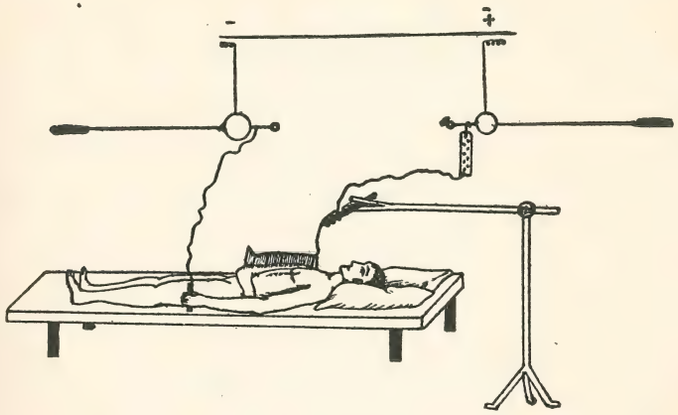


FIG. 66.—Travell's Device for Powerful Brush Effluve from a Metal Wire, Without Sparks. A multiple spark device is inserted between the generator and the wire electrode.

surface receives a similar blast of nitrogen. With a powerful generator this blast or spray may be a foot in length, with a physiologic activity due doubtless to its chemical composition at each pole.

There has been a progressive development of electrodes to ensure this convective blast instead of sparks, the latter resulting even from many fine points at times if they are metallic. The final recourse, with a powerful generator, has been to the moistened wood electrode[1] in which the moisture contained in the wood will not conduct sufficiently well to produce a spark but will convey sufficient for convection through the air. A very

[1] This may be made from the wood of a broomstick, with a screw eye for attachment of conductor at its middle. The distal third is moistened.

effective instrument is the de Kraft Blue Pencil electrode, which yields a blue effluve a foot or more long and is not painful.

It is evident that this static brush effluve differs from the Oudin effluve from a high frequency generator in being an unidirectional stream of ionized air, and that this difference should have some physiologic and therapeutic consequences.

The connections of the static brush effluve are shown in Fig. 65, the polarity being varied as we wish the skin to receive an active ozone blast, when the patient should be connected with the positive pole, or a nitrogen blast, when the patient should be connected with the negative pole. Travell has recently pointed out that if a multiple ball gap (Fig. 66) is interposed

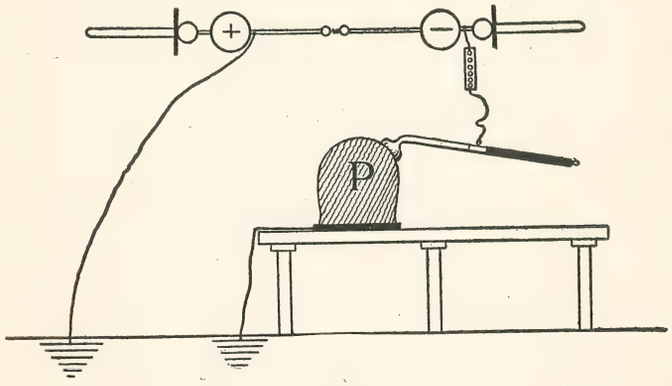


Fig. 67.—Connections for Static Vacuum Tube Current.

between the generator and a wire brush a powerful effluve may be obtained without the risk of sparks.

Therapeutic Indications.—The therapeutic effects of the static brush effluve may be surgical, as in stimulating and sterilizing ulcerations, when the patient should be connected with the positive pole; or counterirritant and stimulating to deeper tissues, when the patient may be negative. Snow and Humphris both advise its use in the relief of local congestion. It should be applied to the bare skin for these purposes, and with a powerful generator a few minutes' application will suffice at a time.

A mild dose of the static brush effluve, often called the static spray or breeze, may be directed to the head or to clothed parts of the body for a revulsive action, or to stimulate hair bulbs.

The effect is that of a localized static bath. The spray electrode for this purpose may be of many fine wires or a whisk, and should be fixed in position for a twenty-minute application, preferably with the Travell multiple gap in circuit. Dry woolen clothing will greatly intensify the effect by a dielectric action.

Static Vacuum Tube Current.—Vacuum tubes may be energized with the static generator as well as with the high frequency generator. Snow greatly prefers the static source,

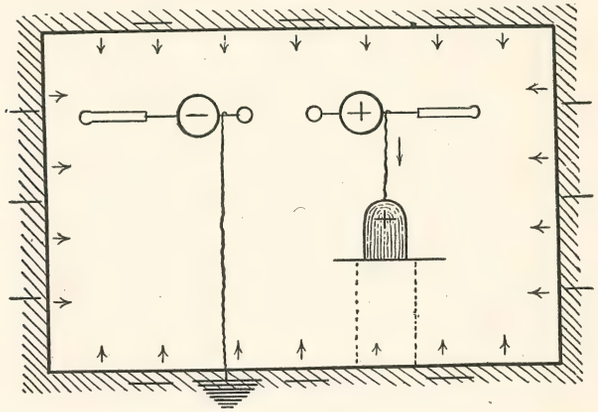


Fig. 68.—Connections for the Static Bath.

and it may be more efficient by reason of ionizing qualities due to its unidirectional character. For the same reason there should be differing therapeutic effects from each polarity.

The patient should not be insulated for this application. An efficient current is applied to the tube by placing it in a shunt path to the spark gap, the other side of the spark gap being grounded, and the tube connected with another ground, or connections may be made as in Fig. 67. Direct application of the tube to the diseased area is the typical form of application, and the method best adapted to alleviate inflammatory conditions of the skin and subdermic tissues for which this modality is recommended.

Static Bath.—As will be seen from the diagram (Fig. 68), this modality is a mild application of the static brush effluve, diffused over the entire body. With spark gap wide open, one pole is grounded and the patient grasps a chain connected with the

other, while connections are completed through the air from the charged floor and walls.

This modality has had varying virtues assigned to it, or none at all. There can be no doubt that it has much value in the treatment of insomnia, particularly if given for a half hour immediately before bedtime, and as an additional treatment for some cases of neurasthenia. The author has usually connected the patient with the anode, grounding the cathode.

Static Induced Current.—For this current the spark gap is closed and the patient placed, by means of wet electrodes, in the

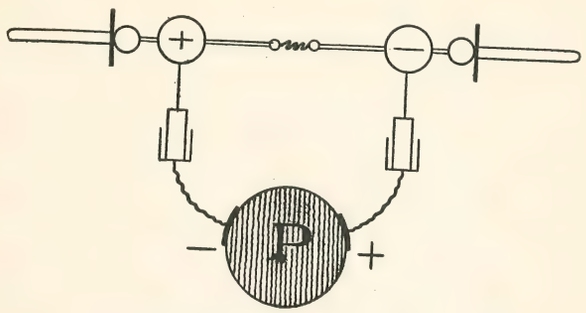


FIG. 69.—Connections for the Static Induced Current. This current may be made rhythmic by one of the rhythmic devices employed with the static wave current.

path of a condenser discharge, preferably small Leyden jars (Fig. 69). The spark gap is then opened an eighth of an inch, or more, according to the muscular response.

This current is an irregularly shaped wave of high, direct current voltage and relatively great amperage. As a consequence of the irregular shape of the waves in particular, the current is so painful compared with rhythmic waves from generators described in Chapter VII that it is rarely used. Its chief interest lies in the historical fact that the late Dr. William James Morton first demonstrated it in 1881—the first demonstration of high frequency currents ever made.

CHAPTER X

ELECTRICITY AND DIATHERMY IN GENERAL SURGERY

Aneurism—Arthritis—Bedsores—Carbuncle—Cystic Goiter—Fistula—Gangrene—Lumbago—Sinuses and Fistulas—Sprains—Synovitis—Surgical Tuberculosis—Ulcers—Wens—Recognition of Motor Nerves During Operations—Tracheotomy by the Cautery Knife.

Aneurism.—The production of firm thrombi in an aneurism with the hope that it will undergo organization with contraction of the sac wall by electropuncture with the anode, was a familiar topic in the electrotherapeutic literature of European countries in the middle of the nineteenth century, cases of both cure and failure being recorded. This method was anodic puncture with the direct current alone. A later method of causing clotting of the blood, that of Moore of London, was by the insertion into the aneurism of fine wire, which, if hard drawn, made a loose coil of many turns to enmesh the clots. In 1864 Corradi combined the two methods by using the inserted wire as an anode, on the coils of which further clotting was promoted by the action of the reduced anions of oxygen, phosphoric acid, etc., of the blood molecules on the blood that remained fluid.

The late Dr. D. D. Stewart, of Philadelphia, and Drs. Hobart A. Hare and Joseph Sailer, of the same city, seem to have done the bulk of this work in America. In a contribution in the "International System of Electrotherapeutics" [1] Dr. Stewart gives a most interesting review of the history of this method to about the year 1894 and reports five cases, the eighth to the thirteenth reported up to that time.

I shall quote the technic of Dr. Sailer, as given in the most recent contribution to the subject,[2] first remarking that a hollow needle of the proper size for the wire may be insulated with a

[1] P. G. 63.

[2] *American Journal of Electrotherapeutics and Radiology*, May, 1920, p. 166.

fine coat of fused hard rubber and sterilized at the same time by the method detailed at page 358, this insulation being thinner than that mentioned by Dr. Sailer and quite sufficient for a single application of a low volt current for one occasion. It may be suggested also that a surgeon should have a skilled electrotherapist as assistant in such a case when possible rather than a mere electrician, as the latter rarely know anything about the unpleasant effect of sudden current variations on a patient.

After pointing out that, as practically all aneurisms of the aorta are of syphilitic origin, the treatment of the underlying cause is the treatment of the syphilis, Dr. Sailer describes the technic as follows:

"The aneurism having been carefully located and determined as nearly as may be, to be sacular, the skin over the point of maximum pulsation is carefully cleansed or sterilized. For this the application of tincture of iodin is usually sufficient. A special needle which is insulated with a porcelain jacket is then thrust through the skin into the aneurism. It may be desirable to make a preliminary incision into the skin or to use a local anesthetic but as a rule neither is required. The pain due to the puncture of the needle is little if any more than that produced by the needle of a hypodermic syringe containing the anesthetic. As soon as the needle is apparently within the cavity of the sac a few drops of blood will usually escape. Sometimes the blood flows in an uninterrupted stream but in no case is the hemorrhage alarming.

"The wire must be carefully selected. The best for the purpose is an alloy of gold and platinum and this is much preferable to silver wire which kinks too readily, or to gold wire which is too soft, and to an alloy of silver and copper which is said to corrode too readily under the influence of the electric current. I have had no experience with the latter but have used both gold and silver and have found them unsatisfactory. It is necessary to have an assistant to hold the spool and feed the wire to the operator who pushes it by very short thrusts into the needle. As a rule not more than a quarter to half an inch of wire can be introduced at each movement although sometimes, when the sac is large and the wire enters freely, as much as an inch can be introduced at once. The great danger is the production of a kink. Both the operator and the assistant should wear rubber gloves and every precaution should be taken to prevent infection. If a kink should occur, the wire should be partly withdrawn and an effort made by pulling and

stroking to straighten the wire again. If this should fail, then the wire must be cut just above and just below the kink and the end of the wire protruding from the needle thrust through it into the aneurismal sac. The introduction of the remaining portion is then continued. There appears to be no disadvantage in using several pieces of wire.

"The amount of wire introduced is more or less arbitrary. It has been my custom to continue the introduction until a distinct resistance is experienced and then to stop. Sometimes fifteen feet can be used and I have on several occasions introduced more than thirty feet. The object is to fill the aneurism as full of the wire entanglement as it is possible to do. When the introduction of wire can no longer be practiced, to the end outside the needle the electrode of a galvanic battery is attached. It is to prevent the passage of the current from the needle to the skin and to restrict it to the wire in the aneurism that the porcelain jacket is required.

"The rules regarding the application of electricity are more or less empirical and fixed. They seem to be fairly satisfactory and should, until the subject has been more carefully studied, be followed implicitly. A large pad is placed over the back, the anode is attached to the wire, the cathode to the pad in the back. The current is first turned on until five milliamperes are passing through. This is continued for five minutes and the current is then increased to ten milliamperes. Each five minutes it is increased five milliamperes until about fifty milliamperes are being passed or until the patient feels a distinct burning sensation. When the burning sensation occurs the current should be reduced and kept at the maximum amount that can be administered without burning until the total time for the application of the current, from half to one hour has expired. The electrode is then disconnected, the wire cut off from the needle, and the end thrust through the needle into the aneurismal sac by a well fitting plunger. The plunger and the needle are then withdrawn and if necessary a drop of collodion placed over the puncture.

"The puncture of the aneurism and the introduction of the wire are comparatively simple. The application of the electricity has in my experience been the most difficult feature of all. Never have I known the electric apparatus to work perfectly. Often it has been necessary to stop the increase of the current at the comparatively low point of 20 to 30 milliamperes. Sometimes it has been impossible to register the current until so much had passed through that I felt the amount was dangerous to the patient. Usually under these circumstances there is a sudden jump of the needle and severe pain is felt in the patient's

chest. It is for this reason that I consider it vitally important to have a skilled electrician in charge of the electrical part of the treatment, and even when this precaution has been observed I have hitherto failed to have a wholly satisfactory administration of the electricity.

"Ordinarily while the wire is being introduced, the pulsation diminishes. There is still further diminution during the passage of the electricity and within a short time the pulsations may wholly cease.

"It must be remembered that this is merely a mechanical measure. If the patient has syphilis the antispecific treatment should be pushed with the utmost vigor. It is only the antispecific treatment that offers any adequate promise of an ultimate cure. The patient should, of course, keep very quiet after the operation for a period of two or three weeks. This does not necessarily mean absolute rest in bed.

"So far I have done this operation fourteen times. I have never had any accident. The patients have all survived the operation and in the majority of cases have been markedly improved. In two cases rewiring was necessary on account of the recurrence of the symptoms, one a subclavian aneurism, one a saccular aneurism of the ascending portion of the aorta. Many of the cases left the hospital in good condition and no subsequent information concerning them could be obtained. The longest case that I have been able to follow has been sixteen months. This case has been apparently restored to health, has resumed his business and claims to feel perfectly well. The X-ray, however, still shows a large shadow at the site of the aneurism. I have been informed by his physician that the mass does not pulsate but there is still a slight tracheal tug.

"On the other hand, the experience in Johns Hopkins Hospital has not been wholly favorable. They have felt that in some instances the life of the patient has been shortened and in only a few has there been any noticeable improvement. Why there should be this difference I do not know."

Adolescent Goiter.—The parenchymal goiters that appear shortly after puberty in young women are usually amenable to percutaneous applications of the direct current, with cathodic pad to the skin over the thyroid and a dispersing pad beneath the shoulders. Several layers of thick absorbent cotton kept wet with warm water, to which several drops of tincture of iodine have been added, form the cathode, with a tinfoil plate laid over it, the patient being recumbent. Ten to fifteen milliamperes are employed for fifteen minutes tri-weekly.

Arthritis.—For a discussion of the lithium and salicylic ions in gouty deposits see page 55. With or without ionization, all forms of arthritis are greatly improved by diathermy, which should precede the ionization if employed at the same sitting.

Bedsores.—The stimulating effect of the cathodic pole of the direct current, about 1 milliampere to the square inch of thoroughly moistened electrode surface for ten minutes daily, has been frequently successful in the treatment of these accidents of the bedridden feeble, provided of course that proper measures are taken to relieve the dystrophic skin from pressure. But a far more convenient procedure is the employment of radiant light and heat from an ordinary electric light bulb, directed on the part by a parabolic reflecting shade, or the use of a vacuum tube or non-vacuum tube thermopenetration. A portable high frequency apparatus would make the latter applications practicable in any bedroom supplied with A. C. lighting mains.

Carbuncle.—Leduc reports five cases of carbuncle of the back of the neck treated by zinc ions, and has observed a remarkable effect in cutting short the disease. He employed the unipolar method with a zinc needle. By turning the current on gradually as much as 30 milliamperes may be used for a duration of half an hour. He states that after the application the pain of the inflammation begins to decrease at once, and in two days all inflammation has disappeared, leaving only the small orifice by which the needle was inserted to heal. The presence of diabetes contraindicates the application.

Cystic Goiter.—The method for the radical cure of cystic goiter to be described originated with the author, and has been employed for a number of years with uniform success. The chief difficulty in its application is the uncertainty attending the diagnosis of a cystic condition of a goiter in some cases, where hypertrophied parenchymal tissue is so elastic that it resembles a cyst on palpation. Uncertainties of this nature may be cleared up by aspiration with a fine needle and abandonment of the treatment if no fluid is secured.

The method is the establishment of free drainage of the cyst by a small opening in the sac through the skin, converted into a temporary sinus by cathodic electrolysis, through which cauterant and antiseptic ions are diffused from a conductor acting as anode. The sac walls and cavity are obliterated gradually by repeated small diffusions of the ions at intervals of three days, final healing of the cavity showing a minute solid scar at the end of about seven weeks.

This apparently bold procedure is made entirely safe from septic or other infection by the development of the mercury ion within the sac every third day, an ion that possesses great antiseptic value. There has been no rise of temperature or untoward symptom of any kind in the cases treated.

Preliminary Puncture and Aspiration.—With the patient recumbent on the operating table, an indifferent dispersing pad is placed beneath the back and connected temporarily with the anodic binding post of the D. C. apparatus. The skin over the most prominent part of the cyst is anesthetized to an area of about a square inch by endermic injections of a suitable local anesthetic, and the rather large needle of an aspirator is prepared to function as a cathode as well as an aspirator by winding the end of a sufficient length of fine copper wire about its shank near its attachment end, the wire to act as conductor. The other end of the wire is attached to the cathode binding post.

The aspirating needle, attached to its aspirator as well as to the electric apparatus, is carefully inserted into the cyst at the proper angle and the contents of the latter withdrawn. A fully developed cyst, with little or no parenchymal tissue overlying it, usually collapses at this time. The needle, still in position within the cyst, is detached from the aspirator and employed as a cathodic electrode, 10 or 15 ma. of power being turned on for ten minutes. This will produce a temporary sinus leading into the cyst, with sealed edges and sufficiently patulous for insertion of the ionization electrode.

The Ionization.—At the completion of the aspiration and the electrolysis of the sinus the needle is removed, the wire of the dispersing pad is changed to the cathode binding post and a short zinc probe with fine point (made from one thirty-second inch zinc plate), heavily coated with mercury,[1] is inserted into the sac through the puncture opening. This electrode has been previously connected by a fine wire with the anode binding post and the dispersing pad changed to the cathode post. Power to the strength of 5 to 15 milliamperes is then turned on and maintained for fifteen minutes. The site of the puncture is dressed after the application and daily thereafter with dilute zinc oxid ointment and gauze. The patient may remain ambulant.

[1] This metal electrode, whether zinc or copper, is *amalgamated* with mercury by scraping it bright, if tarnished, plunging it into a mixture of 1 part sulphuric acid and 3 parts water, and then into liquid mercury. Repeat several times to secure full coating and then wash off the acid with water.

In three days a second ionization with mercury on the zinc probe is made through the opening in the tiny slough. At the end of a week or ten days the skin slough may be found loosened, revealing a sinus sufficiently large for the ready insertion of the ionizing probe into the cyst by which additional ions should be diffused every third day.

At the end of the third week, or sooner if the opening is sufficiently large, the zinc probe should be insulated with fused sealing wax before amalgamation, the insulation leaving a half inch bare at the point. The purpose of the insulation is the protection of the walls of the sinus from further enlargement by confining the ion diffusion to the interior of the sac.

During the course of the treatment the later insertions of the ionizing probe are made less painful by placing a drop of cocain or novocain solution on the opening five or six minutes prior to its insertion. All ionizations are of near 15 minute duration, with a current strength dictated by the sensitiveness of the patient, or between 3 and 10 ma.

The final ionizations, during the fifth to seventh week, are not much more than probings, with a little current for sterilization, until the wound closes fully from the bottom.

This technic may be varied by making a free opening with a small bistoury in the first instance, followed immediately by ionization; or by the use of the mercury ion alone, held in amalgamation on a solid gold probe. The use of the zinc ion in association with the mercury ion, as described above, is thought, however, to be more quickly destructive of the cyst wall than when the mercury ion alone is used. But in any case the mercury ion is essential to the method on account of its high antiseptic action.

Results and Contraindications.—All the cases of cystic goiter treated in this manner by the author have been uniformly successful, and there have been no failures or setbacks of any kind. About seven weeks time is required for the full healing of the little wound.

The chief difficulty in the use of the method is the selection of cases in which a cyst is actually present. The author recalls at least four cases of the few treated in which no cyst was revealed after other physicians had concurred in the diagnosis, and two in which the cyst was smaller than supposed, the exceedingly elastic goitrous tissue rendering palpation deceptive. A prelimi-

nary aspiration is now performed for diagnostic purposes, and if no fluid is found the proposed treatment is abandoned.

In the cases with disappointingly small cysts which were placed under the method the final result was a shrinkage that was at least equal to the bulk of the cyst. The method has no effect on noncystic goiters.

Fistula.—See Sinuses and Fistulas.

Gangrene.—Erythromelalgia—Painful Symmetric Gangrene of the extremities.

The value of active hyperemia by diathermia, etc., in these conditions is shown in the following personal experience:

A conveyancer, aged 64, was referred by Dr. William H. Ziegler, of Philadelphia, November 4, 1921, suffering from extremely painful gangrene of the terminal phalange of the right great toe and the tips of the adjoining three toes, with a deep, brick-dust discoloration of the foot as far back as the instep and heel.

The pain was extreme, day and night, and the odor from the softened slough filled the office. The left leg had been amputated above the knee some two years before, after the failure of prolonged treatment for that foot in the best hands in this country and Europe, only the third amputation of the left foot and leg having healed.

The gangrene of the remaining foot had appeared a month before, following a trivial accident.

The patient was placed under the following treatment: daily applications of 100 watt lamp radiant light and heat, 30 minutes; diathermy, 1200 to 1300 milliamperes 30 minutes; followed by a dressing of dilute zinc oxid ointment.

Improvement was shown daily. The foul odor disappeared in six weeks, the pain during the third month, the brick-dust discoloration was replaced by reorganized circulation and pigmentation of the skin in five months, and the parts were normal and nails regrown in eight months.

During the early part of the treatment the patient nicked the flesh at the corner of the nail on the right ring finger while using the nail file. This was followed by pain in the finger and ischemia, the whiteness extending a half inch from the slight wound. Repeated vacuum tube treatments to this finger quickly restored the defective circulation and caused disappearance of the pain.

Lumbago. — Sacro-iliac Sprain. — Diathermy, applied by means of plate electrodes skillfully adapted to the skin surface over the painful spot and under the abdomen, will greatly hasten the restoration of health in the affected ligaments, and is so

valuable that a sacral belt may well replace the usual strapping for fixation of the parts, permitting ready access to the skin for repeated applications of diathermy.

Sinuses and Fistulas.—The diffusion of zinc ions and zinc-and-mercury ions by a direct current to the whole extent of a sinus, and into the remotest recesses of the infected tissue lining the sinus, is probably the most effectual treatment of these rebellious conditions. A sterile zinc probe, either amalgamated with quicksilver if sepsis is feared or of plain zinc if quicker results are desired, is passed to the bottom of the sinus (as shown in Fig. 71, page 151) and made the anode of a current with a milliamperage proportioned to the size and length of the electrode, the current being maintained for fifteen minutes. A dressing of sterile gauze is then applied, and the procedure repeated at appropriate intervals.

The purpose of the application is twofold: the direct sterilization of the infected cavity by devitalizing the pus-forming organisms within it; and the stimulation of the cavity walls into a condition in which healing is promoted.

The passage of the electrode to the bottom of the sinus is usually free from pain at first, due to the low vitality of the granulating surfaces, and with the cathodic dispersing pad in place on a distant part of the body, one may turn on as much as 20 or 30 milliamperes at the first application and repeat it daily for a time, with a decreasing milliamperage as tenderness is developed, when the frequency should be lessened. At the appearance of the tenderness the external opening should be protected from the current by a fused insulation on the electrode at this site, though the occasional use of a bare electrode throughout its length will be needed at times later to keep the external opening patulous.

As many sinuses and fistulæ are multilocular an effort should be made to apply the ions to a different pocket at each application. This is made easier by bending the electrode before its insulation and insertion.

The first effect is to increase the discharge, which becomes more serous. As the character of the discharge changes and becomes less purulent the strength and frequency of application are still further reduced, until finally the outlet portion only is treated, employing two or three milliamperes at intervals of ten days. At this time final healing and closing of the sinus or fistula may be expected.

Fistula in Ano so treated yields with varying quickness, due to number of loculi or pockets. In true fistula the finger should be inserted into the rectum when the electrode is passed into the fistula through the skin opening, and as the electrode is felt to enter the bowel cavity it is slightly retracted before the current is turned on, or the opposite wall of the rectum may be protected by a rubber spatula passed into the rectal cavity.

Thoracic Fistula.—The following case is an excellent example of the value of ionization in the healing of a thoracic fistula that had existed six months and resisted various methods of treatment:

Mrs. P., aged 37, had been operated upon for an abscess of the pancreas in June, 1920. This was followed by an abortive aspiration of an abscess that had formed above the diaphragm, and later by resection of a portion of three of the ribs on the right side and the evacuation of the abscess successfully in this manner. This latter operation was performed in November, 1920.

The patient was first seen by the author March 2, 1921, with an open sinus at the site of the last operation that had been yielding about two ounces of foul smelling pus daily during the four months since the operation, in spite of daily antiseptic irrigations.

With the patient in a sitting position (which she preferred), and a dispersing pad on the abdomen, a curved, blunt zinc probe of appropriate size was sterilized, amalgamated freely with mercury, and gently inserted into the sinus in the direction of least resistance to a depth of more than three inches, inwards and upwards. With this electrode as anode a direct current was slowly turned on to the point of slight discomfort, which at the first application was 30 milliamperes, and maintained for fifteen minutes. The opening was then dressed with dry gauze. Applications were repeated three times a week with decreasing milliamperages, the electrode being inserted in a slightly different direction at each sitting, and its strength shortly not exceeding 5 milliamperes as this soon became the limit of comfort.

During April and May the disappearance of granulations within the opening and the shrinkage of the latter made it wise to coat the electrode with fused sealing wax at times at the spot in contact with the skin opening, but at other times the electrode was left without insulation to maintain the external opening until the sinus closed from the bottom. The latter applications were of course the more painful. The odor of the discharge lessened rapidly under treatment, becoming more serous than purulent. No amalgamated electrode was ever used for a second time for fear of breakage within the cavity.

During the fourth month of treatment the frequency of application was reduced to once a week and continued at this frequency during the fifth month, with progressive lessening of the discharge and improvement of its character. The last application was made September 2, 1921, and at the next visit, September 12, the sinus was found to be healed from the bottom. The patient's health improved steadily during the treatment, and she has remained well since.

Sprains.—Diathermy is most effectual in relieving the pain from a sprained ligament, being also most effective in promoting absorption of the exudate and hastening the restoration of function in the part. For these conditions Dr. William Benham Snow highly recommends also the static wave current.

Synovitis.—Diathermy is probably the most efficient electrical agency in combating this inflammatory condition. Thermopenetration with the vacuum or non-vacuum tube currents is also effective. The static wave current is also advised by some operators.

Surgical Tuberculosis.—By surgical tuberculosis is meant any tuberculous focus that is accessible to direct local treatment with safety to the patient. Surgeons who interest themselves in physical therapy and who take the trouble to secure the proper apparatus for ionization and to master its simple technic, will doubtless find a broad field for surgical ionization of a variety of tuberculous foci in open sinuses and in unopened deposits that may be reached by an incision through the skin or mucous membranes; but the data on which these paragraphs are based is limited to tuberculous glands in the neck with and without sinuses, and to sinuses that appeared from their refusal to heal under other measures to be of a tuberculous origin.

Hypothetic Basis for the Method.—The author, who first described the method before the Philadelphia County Medical Society in 1901 [1] has used it during the past twenty years with invariable success in the few cases seen in a nontuberculous practice. The hypothesis on which it is based is that the removal of a deposit of living bacilli is best undertaken in such a manner that no fresh wounds will be made in the susceptible tissues of

[1] "A New Treatment for Tuberculous Glands of the Neck with Minimal Scarring; A Method of Sterilizing a Tuberculous Region Through the Lymph Channels," *Proceedings of the Philadelphia County Medical Society,* February, 1901. See also "The Cataphoric Diffusion of Metallic Ions in the Sterilization of Tubercular Deposits," *Proceedings of the International Electrical Congress at St. Louis,* 1904; "Ionic Sterilization in Surgical Tuberculosis," *American Journal of Surgery,* January, 1913.

the host for the possible reimplantation of bacilli not yet killed by the process. The zinc and mercury ions that reach the walls of the retained deposit do not produce a wound capable of immediate reimplantation with anything, but seal the absorbents at this point for from seven to fourteen days, the process having been repeated in the meantime. Observation of the cases treated has led to the belief that an additional effect attended the repeated ion stimulation of the tissues that had permitted the bacilli to grow in them, for after a few triweekly applications to the diseased cavity that was utterly insensitive at first, a gradual increase of tenderness attended the treatment until a normal sensitiveness was present as the wound healed from the bottom.

Exactly the same thing is being done with heliotherapy, it is true, or at least attempted. This valuable resource in orthopedic surgery was not used in these cases, yet satisfactory recoveries were secured in comparatively short periods of time. A combination of the two methods would seem to offer the best procedure for promptly restoring many of these patients to health.

In practice, the theory was found to work with admirable precision. The ions were driven in by direct diffusion from zinc anodes coated with quicksilver by amalgamation and not from solution as in medicinal ionization, the anodes being thrust into the center of the focus or cheesy deposit, so insulated that the power was confined to the active surface in contact with the deposit. The whole deposit was seldom destroyed at one application, but by repeated fifteen minute applications at intervals of one to three days, the white, crumbly detritus being extruded from the open wound in the meantime, together with a small quantity of serum. These office ionizations were rendered possible by the lack of sensitiveness of the wounds and sinuses in these tubercular conditions, particularly when the sinuses were of spontaneous origin, no anesthesia of any kind being required at times. The open wound, covered with simple gauze, was also safe from superinfection of any kind during the intervals between treatment because of the deposit of highly antiseptic mercury ions within it.

So immediate has been the response in all cases in which the ions were thus developed in the very midst of the infection focus that the results were in marked contrast to similar attempts to sterilize immediately a catarrhal cavity of a mucous membrane, such, for instance, as an infected endometrium. The difference is evident when we recall the fact that an infection in a mucous

membrane resides mainly in the mucous crypts, to reach which in the same thoroughness would demand a destructive penetration of the whole thickness of the mucous membrane between the crypts over an extensive area. Equal effects otherwise could only be secured by the impossible plan of placing a tiny anode within each crypt.

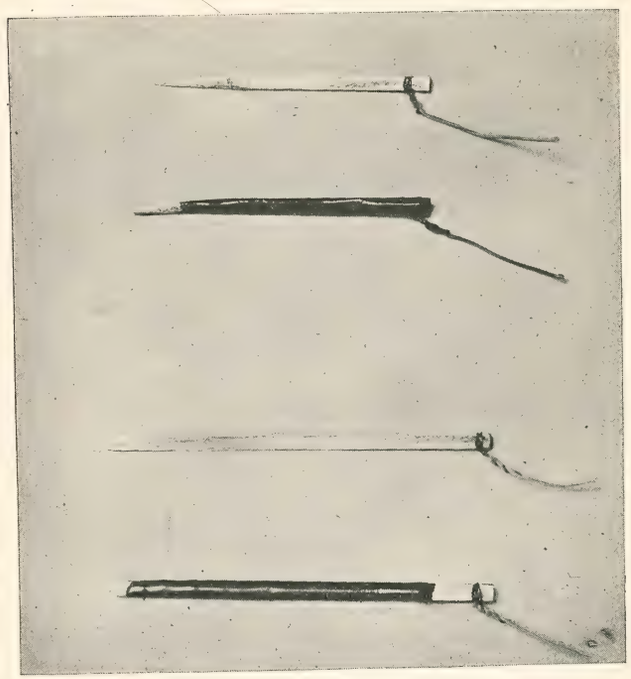


FIG. 70.—Electrodes for Zinc-Mercury Ionization of Tuberculous Foci, Insulated and Uninsulated. Three-fourths size.

The results in the few cases of a single form of tuberculous deposit related below warrant the conviction that the "cold abscesses" of the older writers wherever found, including tuberculosis of bone, and possibly even of joints, may be converted by this method into simple wounds with the normal tendency to heal by granulation from the bottom, and without fear of superinfection during the treatment and the healing process.

Apparatus Required.—A direct current supply, with controller and meter, the latter reading from 1 to 20 milliamperes or more

is needed, or, in its absence, a 20 cell dry battery with cell collector, meter and graphite controller may be used. The applications are always unipolar, that is: with a single zinc-mercury probe as anode and a dispersing pad as cathode.

The Active Anode.—The active pole is of course always the anode. In the early cases the mercury ion alone was used, dispersed from an 18 karat gold electrode, but later it was found that the zinc ion added a greater devitalizing effect to the merely sterilizing action of mercury.

When the tubercular deposit is reached through an open sinus the anode is made of a blunt-pointed strip of 1-32 inch zinc of a width and length suitable for insertion into the sinus without being top heavy after insertion. (Fig. 70.) This is furnished a conductor of light weight by winding the bared end of a sufficient length of No. 32 or 34 copper wire (Browne & Sharpe gauge) about a neck filed in its butt end, and is then insulated with fused sealing wax along the part that will come into contact with the walls of the sinus, if the sinus is large enough, leaving the tip bare. The bare tip is then amalgamated with mercury by dipping it in dilute sulphuric acid and then into quicksilver, repeating if necessary, until an abundant coating of quicksilver covers the active tip.

Should it be desirable to increase the size of the external opening of the sinus, as happens at times during the later stages of the treatment, the instrument is not covered with sealing wax but the zinc-mercury surface is allowed to come into contact along the full depth of its insertion.

When no sinus exists one is made for the insertion of the mercury coated anode by first employing a plain, uncoated and uninsulated zinc electrode needle on account of its needed rigidity, the instrument being thrust into the focus itself or through an opening through the skin and overlying tissue made for it by a small bistoury,[1] under endermic local anesthesia. The plain zinc needle so inserted is made the anode of the first application.

Dispersing Cathode.—Any good dispersing pad, placed on a suitable skin surface at a distance from the anode, will serve as indifferent electrode for the small power used. It should be connected with the cathode or negative binding post of the apparatus.

[1] A large Hagedorn needle will make an excellent bistoury for this purpose.

Details of the Application.—The patient reclines on a couch or operating table with the cathodic pad beneath the back or on the abdomen. No anesthetic is needed in freely open sinuses for the early applications, as the edges and bottom of old tracts are usually quite insensitive. When later the edges of the opening become sensitive as a result of previous treatments, procain or other synthetic analgesic in solution placed on the opening some minutes before insertion will be useful. When there is no opening through which the deposit can be reached one is made as described above.

With the anode inserted, its shank is held in an immovable position by a guy strip of adhesive plaster attached to the wire near the electrode, Figure 71, permitting movements of the patient without jarring the instrument out of position, any movement of the anode after the power is on being liable to cause pain.

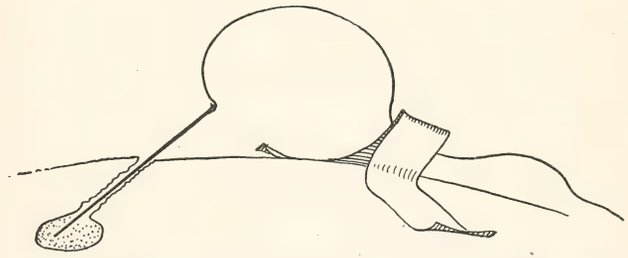


FIG. 71.—Showing Method of Holding Electrode Immovably. A strip of adhesive plaster holds the wire by being attached to nearby skin, permitting movement of patient without disturbance of electrode.

Power is turned on gradually to a point short of discomfort, whether this be when 2 or 20 milliamperes is reached, and allowed to flow for fifteen minutes. It is then turned off equally gradually, the anode removed and the opening covered with a small dressing of lint or gauze on which a little dilute zinc oxide ointment has been placed—or better, the ointment is heated and poured over the wound before the lint covering is put on.

The treatment is repeated at first triweekly or biweekly and later once a week until the wound closes from the bottom, the milliamperage being lessened as the sensitiveness of the skin edges increases and the cavity approaches the condition of a healthy wound.

The final scar is small and inconspicuous.

Illustrative Cases.—Case 1. Male stenographer, in his early twenties, had had one cervical gland removed a year before being seen. Another enlarged gland the size of an almond then showed near the scar. This was opened under ethyl chlorid spray and received eleven applications during seven weeks. No further glands became enlarged, and his health was greatly improved when the case was shown to the Philadelphia County Society a year or more after. He was in rugged health when seen in 1911.

Case 2. The second patient, exhibited with the first, in excellent health on the occasion mentioned, a year and a half after termination of the treatment, was also a stenographer, female, with a history of tuberculosis in grandparents, and a sister and brother then suffering from consumption. Examination had shown two enlarged glands on the right side of the neck back of the sternomastoid muscle, rather alongside each other than in the same chain, with several smaller ones below. There had been stiffness and pain in the neck, aggravated by her work.

She received nineteen applications to one gland during three months, followed by a shorter treatment of the other gland. The general health improved distinctly, and when she was shown to the Society the two scars were each less than an eighth of an inch in diameter.

Case 3. A young lady of 29, profoundly anemic and the probable subject of a number of internal tubercular colonizations, was referred by Dr. Ulrich, of Chester, Pennsylvania, January 3, 1901, with a number of open wounds in the right side of the neck that had failed to heal after various operative procedures, during which tubercle bacilli had been diagnosed in the removed material. The left side of the neck presented an almost continuous scar from operations that had finally resulted in healing.

The open wounds in the right side of the neck were so insensitive that 20 milliamperes were readily borne in one of them at the first application without anesthesia of any kind, increased sensitiveness compelling a later reduction to five. The patient was under treatment a number of months before final healing of all sinuses was secured, probably because the zinc ion was not used in this case but the mercury ion alone, diffused from a hollow 18 karat gold electrode. A large number of small palpable glands remained beneath the healthy skin after all wounds had healed, and it was decided to apply the X-ray to them as a preferable mode of treatment on account of their number and small size. The patient failed to return for this, however, and when seen again six months later these enlargements had disappeared without further treatment.

Case 4. A boy of 3 years was first seen March 4, 1901, with a soft tumor below the ear on the right side of the neck measuring 3

inches in length. Fluctuation could be made out. It had first appeared eighteen months before.

The cavity was opened under chlorid of ethel spray, a considerable quantity of pus flowing out, and a mercury ionization of 5 milliamperes made to the insensitive cavity with a gold electrode. After five ionizations large quantities of white, curdy material were removed with the dull curette under a little chloroform and 50 milliamperes used to drive in mercury ions for two minutes. The wound had entirely healed six weeks later, with much improvement in the baby's health.

Case 5. The daughter of a physician, aged 10, was referred by her father January 25, 1908, with a single enlarged gland in the neck the size of a pigeon's egg. During the treatment of this case with small doses of zinc-mercury ions under local anesthesia, her aunt noticed that her circulation quickly improved, night terrors disappeared, and she was more willing to play outdoors in winter weather than formerly. A pin head scar only was left after the wound healed.

Case 6. Delicate girl of 9 was referred by Dr. Ulrich January 4, 1909, with a tumor the size of a pigeon's egg below the angle of the jaw that showed fluctuation on palpation. The gland had been enlarged for five years, becoming worse recently after an attack of tonsillitis. A dessertspoonful of pus escaped when the cavity was opened. She received ten applications of mercury ions from a gold electrode during the following three months. Restoration of health was complete, with a scarcely perceptible scar. She was seen in 1920 in robust health.

Case 7. Helen R., aged 15, was referred by Dr. Seidel of Reading, Pennsylvania, March 7, 1912, with an open wound immediately above the left clavicle (Fig. 72) that had refused to heal after being open for some time. The opening led to quite a large cavity. Zinc-mercury ionizations were begun with 25 milliamperes for half an hour, repeated at intervals in diminishing doses. Ten ionizations were made in the remainder of March; eight during April; seven during May; two during June; and one each during July August and September. The final photograph was taken January 14, 1913. There has been no recurrence.

Case 8. A girl of 5 years was first seen November 13, 1912, with an enlarged gland on the left side of the neck that had been lanced two months before but had failed to disappear after the wound healed. Zinc-mercury ions with 5, decreasing to 2 milliamperes were applied thirteen times during November and December and the patient kept under observation for a time. She was examined two years later, revealing a small movable gland alongside the scar. Her general health had improved. A letter received in 1920 states

that her health continues good, but the small palpable gland can still be felt.

Case 9. A young lady art student, seen first April 4, 1917, had had an open sinus beneath the left ear for three months, following the breaking down of a gland. Nine applications of zinc-mercury ions, 10 to 2 milliamperes, were made during five weeks. She was seen three years later in excellent health and with a very small scar.

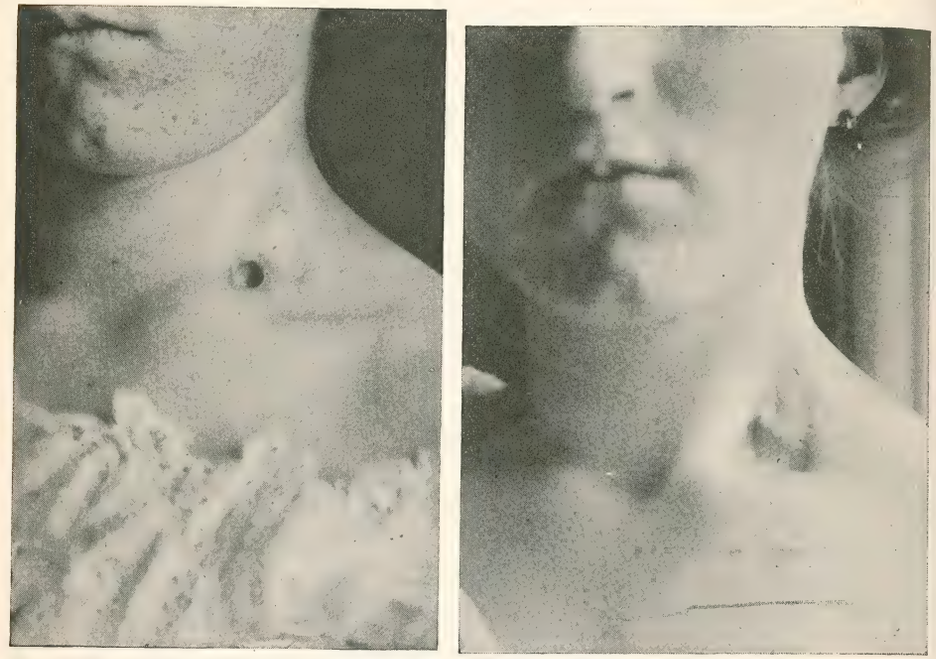


FIG. 72.—Case 7 Before and After Zinc Mercury Ionization.

Ulcers.—The works of Leduc and Lewis Jones contain many detailed instances of rapid healing of indolent ulcers, whether tropical ulcer, diphtheritic ulcer or syphilitic ulceration by zinc and copper ions, the tendency being of late to favor the zinc ions, or zinc and mercury ions. The anode was usually a plate cut from the thin metal of a size and shape to cover the ulcer. Several applications of currents of about 10 milliamperes per inch of square surface were made with durations of fifteen to twenty minutes, the part being dressed meanwhile by simple petrolatum.

There was usually improvement after the first application and healing in a few weeks, after other means had failed.

Finzi[1] made experiments in the relative value of zinc and copper ions by treating part of an ulcer with zinc ions and part with copper ions, finding that the part treated with zinc healed more quickly than that to which copper was applied.

Wens.—A wen is a retention tumor formed by the closure of the excretory duct of a sebaceous gland, the contents being cheesy sebum. There is no reason whatever for a bloody operation for the removal of the sac of such a tumor, even when large. When small, it may be punctured without anesthesia by zinc needles and destroyed by unipolar zinc ionization, the sebum being evacuated with an ear spoon during a pause in the ionization, or if large, local anesthesia may be used. The sac should be thoroughly destroyed at this application, the further ionization, if needed, being applied after the debris has been extruded, a week or two weeks later.

Electrical Stimulation of Exposed Nerves for their Recognition at Operations.—In an operation for the correction of traumatic lesions of peripheral nerves after industrial accidents and war wounds, or for the implantation of a healthy proximal portion of a nerve under Wallerian degeneration as a result of poliomyelitis, or, in fact, in any operation which encounters motor nerves the positive recognition of which would be helpful to the surgeon, the stimulation of the nerve by a harmless current by means of an aseptic bipolar electrode is readily done. If the stimulation is applied below the lesion the nerve is instantly recognizable from the muscles that respond. Moreover, as shown in a valuable paper on the subject by Kraus and Ingham[2] one may identify the fibers of nerve branches by stimulation of particular portions of the nerve trunk and thus make more perfect appositions of similar neurons.

In selecting the current for this purpose it should be recalled that the tissue resistance of a moist nerve between the closely applied poles of a bipolar electrode is enormously less than the resistance between poles placed on the skin over nerves. A faradic battery giving a current of very low volume and high voltage is therefore indicated. Drs. Kraus and Ingham employed a Harvard Inductorium and set the apparatus for the test at the point

[1] *Proceedings of the Royal Society of Medicine,* Vol. II, p. 140.

[2] *Journal of the American Medical Association,* February 28, 1920, Vol. LXXIV, p. 587.

at which the smallest minimal contraction could be obtained in a neighboring muscle, finding that a greater effect was produced in the bare nerve.

A convenient electrode for this purpose is made from two brightly polished, round end steel knitting needles as follows: Procure two pieces of pure rubber tubing with calibers that the knitting needles will fit snugly when the rubber tubing is passed over them, the pieces being somewhat longer than the needles. To the inactive end of each knitting needle attach a sufficient length of fine cotton covered copper wire (No. 34, Brown & Sharpe gauge) to act as conductor from the inductorium to the field of operation. The wire is attached by baring the end and simply wrapping it tightly around the end of the needle, the rubber tubing holding it in place later.

With some talcum powder puffed into the rubber tubing for lubrication, the knitting needle can be readily pushed into its caliber, covering the whole needle and the wire joint at the farther end and thus holding the wire in place. A quarter of an inch is left bare at the tip. With both knitting needles thus covered and attached to a separate conducting wire, they are bound together by small rubber bands, thus forming a bipolar electrode with poles about the correct distance apart. The electrode and the whole of the conducting wires may be sterilized by boiling before operation, and kept in a dry and aseptic condition until needed at the operation.

The freed nerve is held by a glass rod as in a cradle, and the electrode points placed longitudinally on the nerve.

Tracheotomy by the Cautery Knife.—The cautery knife is being so largely displaced in operations on malignant tumors by the more penetrating and better controlled cooking heat of bipolar electrocoagulation operations that little mention has been made of it hitherto in this work. The apparatus and instrument required are described at page 59. Its use in a limited class of incisions in benign conditions to merely replace the knife, where union of the incision by first intention is not desired, has probably not received the attention that it deserves. The absence of bleeding and of all need of ligating small vessels during the incision, as well as the impossibility of infecting the wound during and for days after the incision, make it a valuable method of opening the trachea in an emergency for the insertion of a tube, particularly if a skilled surgeon is not at hand and antiseptic precautions are difficult. The absolute bloodlessness of

the procedure is a great assistance in locating the trachea, and eliminates the insufflation of blood at the moment that the trachea is opened. The small rings of the trachea must be held apart by retractors during the insertion of the tube.

The hot knife of the Radiotherm H. F. generator would also seem to be well adapted to this operation.

CHAPTER XI

ELECTRICITY IN INDUSTRIAL AND RECONSTRUCTIVE SURGERY

Electrodiagnosis—The Faradic Test—The Galvanic Test—Nerve Test—Muscle Test—Normal Formula of Polar Response in Muscles—Wallerian Degeneration and the Reaction of Degeneration—Degeneration Reaction in Nerves—Degeneration Reaction in Muscles—Objectives in an examination for Degeneration Reaction—Prognosis as Affected by the Occurrence of Degeneration Reaction—Examination of Particular Nerves and Muscles—The Galvanic Condenser—Progressive Galvanic Test—The Removal of Lead and Mercury from the Tissues.

The treatment of the wounded in our reconstruction hospitals during and after the late war was fortunately undertaken under auspices that permitted a free application of the various physical forces as therapeutic aids, and the impetus thus given to physical therapy will doubtless be transferred to those wounded in the industrial establishments of the country. When it has been manifested by the clinical experience of army surgeons that the systematic use of these measures in the reconstruction hospitals saved suffering, lessened the time in hospital and shortened the period of invalidism, the financial value of these savings in industry will surely demand similar measures in industrial surgery, where considerations of time lost at work and the legal compensation costs are involved.

Preceding chapters on Rhythmic Currents, Ionization and Diathermy will indicate the methods of application of electric modalities to the absorption of exudates, the maintenance of nutrition in muscles cut off from their nutritive center, the sclerolysis of scar tissue, and the relief of traumatic neuritis. These methods may be used separately or alternately in a given case, thermotherapy from some source, such as low candle power lamps, being particularly advised preceding the rhythmic stimulation of muscles.

An illustration of the value of physical therapy to employers

and insurance companies in lessening the period of disability of employees is contained in a report of two cases treated at the rehabilitation clinic of the Aetna Insurance Company at Syracuse, New York, conducted by Dr. Chas. P. Hutchins:

Case A, admitted to the rehabilitation clinic October 25, 1922, with subacute arthritis and no motion of the carpal and carpo-radial joints; fibrous proximal interphalangeal joints, index and second fingers, with hyperextension; no flexion or extension of wrist, and pronation of but 30 degrees. One hundred per cent. loss of hand reported by his physician.

Patient discharged from rehabilitation clinic February 2, 1923, with slight flexion and extension at wrist, voluntary flexion of fingers and no pain.

Final financial adjustment May 3, 1923; award sixty-six and two thirds of hand. Cost of treatment, $161.36. Saving on incurred loss: eighty-one weeks at $10.27, or $831.87. Net saving: $670.51.

Case B, admitted January 27, 1923, with vicious union of radius three-quarters of an inch from lower end, following open operation for replacement two weeks before. Permanent fixation of metacarpal of thumb in adduction with fibrous degeneration of thenar muscles; loss of thumb and index finger, for they block each other. Seventy-five per cent. loss.

Discharged March 2, 1923, with complete recovery of posture and function of wrist. Final adjustment: award of 50 per cent. of hand. Cost of treatment $329.06. Saving on incurred loss: 61 weeks at $13.35 per week, or $813.13. Net saving: $484.07.

Electrodiagnosis.—In conditions following traumatism to a motor nerve, as well as in diseases that produce a similar disorganization of the neuron, important diagnostic and prognostic aids may be derived from muscle and nerve testing with certain electric waves. This is due to the fact, first shown by duBois Reymond, that a normal muscle responds differently to cathodic and anodic waves; and, as first carefully pointed out by Erb, that in one definite condition, that of Wallerian degeneration of the neuraxon, this normal formula of muscle response is reversed, constituting a *serial change,* the degeneration being further indicated by a change in the mode of contraction of the degenerated part, known as the *modal change.*

The eliciting of these responses is therefore a test of the presence of Wallerian degeneration; a measure of its extent; and an indication of its probable prognosis.

When it is further understood that Wallerian degeneration is always more or less present after any serious injury to the motor tract in the spinal cord, roots of the motor nerves, or the motor nerves themselves—its presence and degree indicating approximately the date of the injury and the probable time required in convalescence, and its absence constituting indication of fraud in a claim based on an alleged injury after which it should be present—the value of nerve and muscle testing to elicit these responses is evident, both as a guide in therapeutic work and as evidence in medicolegal proceedings.

The belief on the part of many surgeons that these tests are abstruse and difficult has not only interfered with treatment

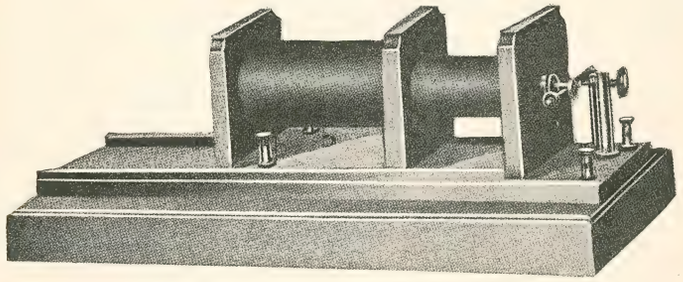


Fig. 73.—DuBois-Reymond Type of Faradic Coil. The fine wire secondary helix slides over the coarse wire primary helix, the secondary current being weakest when the two coils are farthest apart.

based on accurate diagnosis, but caused many worthy claims to be lost in the courts and many unworthy claims won.

Two kinds of electrical waves are employed in practical testing: the automatic wave of single or consecutive inductions of the induced or faradic current, and individual waves of the direct or galvanic current produced by closing or opening the circuit by hand or by foot. Condenser currents have recently been employed in England and in reconstruction hospitals in this country and are described below. These are intended to replace the galvanic wave.

The Faradic Test.—These are isolated inductions rising in the secondary helix of the well known faradic battery when the current in the primary wire is broken (Fig. 27, page 67).

It is unfortunate in some respects that the faradic battery is not as universally found in electrotherapeutic outfits at the present time as formerly, for, if not essential in electrodiagnosis, it forms a most important preliminary test. Some of the older coils were arranged to produce isolated inductions by means of a slow pendulum interrupter. That is convenient but not necessary, as the rapidly successive waves produced by the ordinary spring vibrator are usually sufficiently delicate for the detection of the minimal response.

The types of these coils have varied greatly from the original duBois Reymond apparatus, in which the secondary coil slides over the primary, but this type remains to-day the best for diagnostic testing, as the strength of the current is controlled with great readiness by sliding the upper coil over the lower, a millimeter scale registering the progressive covering of the primary coil by the secondary; zero of the secondary current, which is used in preference, being with the coils apart, and the strongest current when the secondary or upper coil has quite covered the primary or lower. But any form of faradic coil may be used if its regulation is understood by the operator and its minimal strength is tested on himself before employment in the test.

But one active pole is used in faradic testing. This is the cathode of the wave impulse arising in the coil when the inducing circuit is opened. (The opposite induction is physiologically but not chemically negligible in these coils.) The electrode giving the cathode may invariably be identified in any faradic apparatus by the following procedure: Grasp one moist electrode in the palm of the left hand and, holding the other moist electrode by its handle in the right hand, with a mild current running, touch the skin of the left hand between the base of the forefinger and the thumb with the wet electrode held in the right; reverse the poles at the pole-changer and repeat several times: the cathode will be found to be many times sharper than the anode.

In testing with the faradic current the anode is connected with an indifferent pad placed on the sternum or between the shoulders and the cathode over the nerve or motor point, or, with this current, a sort of bipolar application is often best as more nearly localizing the action to the spot desired. In this case the cathode is similarly placed on the motor point, but the anode is applied over the body of the muscle to be tested or just below the motor point in the case of a nerve. Electrodes that present a surface of one or two centimeters in diameter are the most convenient. The conducting surface of each electrode should be amply cov-

ered with absorbent cotton, thoroughly saturated with water, the cotton being attached to the active electrode while dry by twisting the electrode in a sufficiently large and thick wisp of the latter in a manner similar to the covering of an applicator. Duchenne (du Boulogne) long ago pointed out the value of small ball-shapped wooden handles to such electrodes for greater convenience in the holding of both electrodes in one hand.

The purpose of faradic testing in pathologic cases is, first, the determination of the presence of the response, and, second, the minimum current that will produce it. Now we have no means of accurately measuring faradic currents, but by turning them on gradually we may note the position of the coils or other regulating devices and make this our record. In order to relieve this unnecessarily obscured subject of as much useless detail as possible, I should say that exact figures are not important in faradic testing. The current produced at certain positions of one coil is no criterion to that produced in another. It is usually a question of extinction of response or of normality, though various degrees of diminution may at times be found by comparing organs of opposite sides of the body in unilateral affections.

The diagnostic value of the faradic wave is due to the fact that the quantitative response of a nerve or muscle to this current is lessened or extinguished when the trophic supply of the muscle or nerve has been interfered with or destroyed (Wallerian degeneration). This is interesting when viewed in connection with the increased response shown by a muscle in the same condition to the galvanic wave, and can only be due to the briefness and small milliamperage of the faradic wave (see page 66). The pathologic muscle or nerve is apparently unable to respond in so short a time. The duration of these induction waves has been measured and found to be in the neighborhood of the one four-hundredth part of a second. As to the milliamperage of these waves that actually reach the motor point, it must be an extremely small fraction of a milliampere, doubtless far less than a thousandth part. In voltage alone it is relatively great, being possibly 30 or 40 volts.

The Galvanic Test.—In testing nerves or muscles with the direct or galvanic current we employ the current of the mains when these are supplied with the direct current, which is true only of the central districts of our large cities, or when a private lighting installation employs this current. Otherwise one must install a motor-dynamo to transform the alternating current usually employed in our modern lighting systems into the direct current, or else use a battery of 20 or 40 dry cells connected in series. Portable batteries of the silver chlorid or small dry cell types are most convenient and light and sufficiently strong for these testing purposes. Before use, the correctness of the polarity of the apparatus should be tested (page 26).

In either case the current is controlled and measured by the use, in the circuit, of a proper controller and accurate meter—the latter being inserted between one pole of the controller and a patient's binding post so that only the current actually traversing the patient will be measured. The meter should be of scale to readily indicate to the eye the small currents used, which vary from one-half to ten milliamperes. All wall plates and similar apparatus are, of course, excellent for this purpose when supplied with the direct current and a sufficiently sensitive and accurate meter.

The Active Electrode is similar to that employed with the faradic current or may be slightly larger, with a skin contact two and a half centimeters in diameter. It must have an adequate covering of absorbent cotton to hold a free supply of moisture. A little chlorid of sodium may be added to the water, but it is not essential.

The Indifferent Electrode.—As this test is usually strictly unipolar, the indifferent electrode, also well covered and saturated with warm water, is held in contact with a distant part of the body by bandaging, adhesive strips or otherwise. It should be not less than 10 x 10 centimeters in area to lessen resistance at this point.

Circuit Closer.—This may be a foot push-button,[1] which remains open except when pressed, intercalated in the circuit between one binding post and the patient; the pole-changer of the apparatus worked by the right hand; or even a methodic making and breaking of contact by holding the pin of one of the conducting cords in the right hand and pressing it firmly against the side of the binding post for the one second required for the circuit closer. Spring circuit breakers in the handles of electrodes, though much used formerly, are undesirable on account of the slight movement of the handle masking the muscle movement.

Details of Galvanic Test.—The active electrode, held in the

[1] The Daisy Floor Tread, made by Ansonia Electrical Co., Ansonia, Connecticut, is a cheap and excellent foot circuit closer, and may be procured at any electric supply house.

left hand, is pressed firmly on the skin over the point to be tested leaving the right hand free to work the controlling apparatus, and the current is turned on to one or two milliamperes at the controller and allowed to flow a second. With the controller remaining as placed, the circuit is abruptly opened in some metallic part (circuit closer) and closed again for a second a little later. If no response is obtained increase the current at the controller and repeat until the first flicker of the muscle is seen, when the number of milliamperes required to elicit this at closure is noted and recorded.

Begin with the cathode, and then change the direction of the current at the pole-changer, or by reversing the wires in the binding posts, to make the active electrode the anode, and repeat the procedure, noting the number of milliamperes required to produce the minimal contraction at anodal closure. The result in a normal nerve will show *greater irritability at cathodal closure than at anodal closure,* shown by a less number of milliamperes being required at the former.

Now, one may ascertain the milliamperage required to produce contraction at anodal opening—usually about the same as anodal closure. Finally, if not too painful, a strong current will produce a flicker at cathodal opening, though this is usually preceded by a duration tetany continuing from the cathodal closure.

Both faradic and galvanic tests are best made after the part has been warmed by thermotheraphy in some manner, and the patient should not be fatigued when they are made.

Nerve Test.—The faradic test is first made. If less response is obtained than at the corresponding motor point of the opposite side of the body, this fact is recorded, with a statement of the position in millimeters of the secondary coil.

The galvanic test is then made with the same electrodes switched to the circuit. A quantitative change only is found in pathologic nerves in the shape of diminution of response to this current, diminution of excitability being shown by more current being needed to produce a contraction at cathodal closure.

Muscle Test.—With unilateral injury or disease, the actual motor point of the muscle to be examined is located by the faradic current on the normal side. The same current may then be used at the motor point of the suspected muscle, followed by the cathode of the galvanic current.

Normal Formula of Polar Response in Muscle.—This refers to the galvanic responses in muscle alone, which, when normal,

will require less current with the cathode on the motor point at closure of the circuit than with the anode on the motor point at closure. In other words, with the same current milliamperage there will be greater contraction at cathodal closure than at anodal closure. This is readily shown by the formula: CaCl Contraction > AnCl Contraction.

The two closure contractions, that with the cathode active and that with the anode active, are sufficient as a test for all practical purposes, and is usually all that can be obtained in muscle, though the full *serial relation* of the two closure contractions and the two opening contractions in nerves are as follows, *when the same milliamperage is applied*:

CaCl—greatest contraction.
AnCl—next greatest contraction.
AnO—weak contraction, rarely produced in muscle.
CaO—weakest contraction, rarely produced in muscle.

Such is the normal formula of muscle response, in *serial* relation to closure and opening of the circuit at the two polarities.

The *mode* or *quality* of this normal contraction is that of a quick jerk.

WALLERIAN DEGENERATION AND THE REACTION OF DEGENERATION

The reaction of degeneration, first described by Erb of Leipzig, is a phenomenon of neuromuscular excitability by which the presence of Wallerian degeneration of the peripheral motor centers or nerve conductors is indicated. It has, therefore, a narrow interpretation, but presents indications of great value in the differential diagnosis between cerebral and peripheral palsies. It enables us also to locate the exact site of the *locus morbi* in peripheral affections and injuries of the motor apparatus, as well as to estimate their extent and probable prognosis.

To indicate the meaning of this degeneration one must review the facts concerning the motor neuron. This is a physiologic and embryologic unit consisting of a primary motor cell in the cerebral cortex, a secondary motor cell below, and a conductor connecting these two together and with the terminal muscle. The secondary motor cell-center for the cranial nerves is situated in the medulla and for the spinal nerves in the anterior horns of gray matter of the cord. These primary and secondary motor centers are connected by a conductor called a neuraxon. From the secondary motor center another neuraxon connects the second-

ary center with the end organ in the muscle. We have thus two neuraxons in each motor neuron—one above the secondary center and one below it.

Now, Waller, an English physiologist, first pointed out that these neuraxons not only conduct nerve force in the shape of motor impulses, but also trophic or nutritive force from the respective centers, and that injury to either center-cell or conduct-

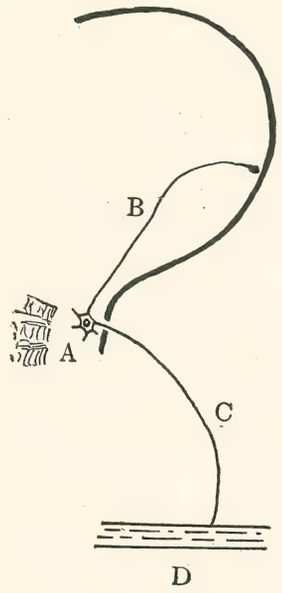


FIG. 74.—Diagram Illustrating Test for Wallerian Degeneration. A, motor-trophic cell of anterior horn of gray matter of spinal cord, or secondary motor center; B, portion of motor neuron within the skull; C, portion of motor neuron accessible to electric stimulation; D, muscle fiber.

ing neuraxon will cause degeneration of the neuraxon extending peripherally from the injury, *but that this degeneration when occurring above the secondary motor center, will not affect the neuraxon below the secondary center* (Fig. 74).

Injury to a motor neuraxon above the secondary center, within the brain (apoplexy, cerebral tumors, etc.), will, therefore, not produce Wallerian degeneration in the motor neuraxon below the secondary motor center, though causing degeneration of those above this center.

The discovery of Wallerian degeneration in any peripheral nerve, nerve-ending or muscle is, therefore, a certain indication that the injury or disease causing it is situated *in* or *below* the secondary motor center in the medulla or cord.

The Erb reaction, the reaction of degeneration, which indicates the presence of Wallerian degeneration, is a certain clinical sign, therefore, of disease or injury of the secondary center or its afferent neuraxon, as we have no way of applying these test currents to the neuraxon between the primary center and secondary center situated deeply in the brain.

The degeneration of the secondary motor center, whether caused by traumatism, toxic action or infection, or injury of the peripheral neuraxon itself from such agencies, will cause degeneration of the neuraxon and its terminal portions, the end plate and muscle fiber, the degeneration extending peripherally from the point of injury. Below the point of injury the neuraxon is not merely a "dead wire" in electricians' parlance, but a degenerated conductor also. Within forty-eight hours after the injury the neuraxon may be said to curdle, in ordinary language, and, in proportion to the degree of injury, it becomes incapable of transmitting either volitional or trophic force or of initiating function on excitation. In other words, not only volitional motility and trophic conduction cease, but, most important of all for our test, the electrical current wave applied to the curdled neuraxon fails to cause contraction in the muscle supplied by it.

As viewed by the physicist, we have here a protoplasmic conductor of such delicate constitution that a breakage of the circuit of the forces conveyed by it will be quickly followed by its death, because one of the forces thus interrupted is apparently essential to its integrity from hour to hour, for it requires but a few days for dissolution of the neuraxon after injury. This change is evident within forty-eight hours as stated above, and within three days after complete severance or a crushing injury a profound alteration occurs in this conductor peripheral to the injury. I will not repeat the histologic description of this degeneration so often given. It may be described in plain language as an invitation to the phagocytic cells of the sheath of Schwann, one of the insulating envelopes surrounding the neuraxon, and other cells of the surrounding tissues, to a feast, the devitalized substance of the conductor being quickly consumed.

In complete destruction of the neuraxon the final result is a total disappearance of the neuraxon peripheral to the injury and

ultimately a condition of sclerosis, representing the altered remnants of the collapsed insulating envelopes. Even then regeneration may occur, and this is invariably by a budding projection from the central end of the severed neuraxon. This regenerating end will grow best into its old conduits, the collapsed insulating membranes (medullary sheath and sheath of Schwann), but may be turned into other nerves by artificial anastomosis. It is said to grow at the rate of about a millimeter per day.

Parallel with the changes in the nerves are analogous histologic changes in the muscles supplied by them. The first phenomenon noticeable is a progressive diminution in the size of the muscular fibers, which becomes distinct during the second week, is very considerable after the lapse of several weeks, and, in incurable cases, leads to complete disappearance of the fibers. The transverse striation becomes somewhat indistinct, but fatty or granular degeneration of the fibers is observed only exceptionally. A considerable increase in the number of the muscle nuclei, which are accumulated in masses or chains, occurs at the same time; finally, a chemical change in the muscle develops and is manifested by the greater tendency of these muscles to the development of so-called waxy degeneration.

Cellular infiltration and connective tissue proliferation in the interstitial connective tissue of the muscles also occur, and the terminal result is an evident cirrhosis of the muscle, whose atrophied and small fibers appear surrounded, after the lapse of a few weeks, by large tough bands of fibrous tissue. In incurable cases the entire muscle is transformed into connective tissue, which may afterward become the seat of a deposit of fat. As soon as the regeneration of the nerves occurs the muscle is slowly restored to its normal condition, though this requires a long time (Erb).

In clinical practice we may have many degrees of Wallerian degeneration, from that accompanying a slight rheumatic or exposure neuritis of the facial nerve, or a temporary pressure palsy of the musculospiral lasting but a few days, for instance, to degeneration so complete as to be permanent.

It is an interesting fact that during the process of regeneration of the neuraxon it may arrive at a stage where it will conduct volitional impulses, showing a return of muscular motility, before a response to the electrical stimulus is obtainable. This shows that the "irritability" of a neuraxon to stimuli at indifferent points (a peculiar attribute of this conductor as compared

with the wire conductors of other forces) is an endowment requiring a more robust condition than that demanded to transmit its power nerve force. An additional fact of interest is the possibility of an electrical stimulus applied above the lesion causing a response in the muscle if the latter has not degenerated too much, the physiologic impulse aroused by the stimulus passing through the diseased part of the neuraxon where the neuraxon itself is nonexcitable to this stimulus.

DeR in Nerves.—The changes in the response of the motor nerve affected by Wallerian degeneration are similar with both the faradic and galvanic currents, and are *quantitative* only. There is no change in the polar formula, but simply a diminution of excitability, shown by greater strength of current being needed to elicit normal response, this diminishing excitability proceeding quickly to complete extinction in severe cases in about fourteen days. The eliciting of this result in the muscles supplied by the nerve is a sign that the lesion is higher up in the nerve tract than the point tested.

The diminution and extinction of faradic and galvanic excitability in a nerve corresponds exactly with the progress of Wallerian degeneration in the neuraxons concerned. With regeneration of the neuraxons the excitability to both currents returns *pari passu;* but the electrical excitability reappears somewhat later than the conductibility of the neuraxon for voluntary impulses or for electrical excitation applied to the central portion. This seems to depend on the stage of development of the regenerated conductors; they do not appear to become excitable until they are provided with a medullary sheath of a certain width, while they are capable of volition-conduction at an earlier stage. With the increasing development of the young conductors the excitability increases, but it remains below normal for some time, partly on account of the insufficient development of the nerve conductors and the cirrhosis of the envelopes, and to a still greater extent on account of the atrophy and cirrhosis of the muscles, which do not respond with normal vigor to stimulation proceeding from the nerves.

DeR in Muscles.—During the first week of Wallerian degeneration of a motor neuraxon the muscle fiber supplied by it shows a steadily decreasing *quantitative* response to both currents quite similar to that occurring in the nerve, but possibly more rapidly decreasing to the faradic wave. It is thought that this corresponds to the increasing disorganization of the end

plate, or junction of the neuraxon with the sarcoplasm of the muscle fiber.

During the second week of the Wallerian degeneration, however, the most characteristic changes occur in the galvanic re-

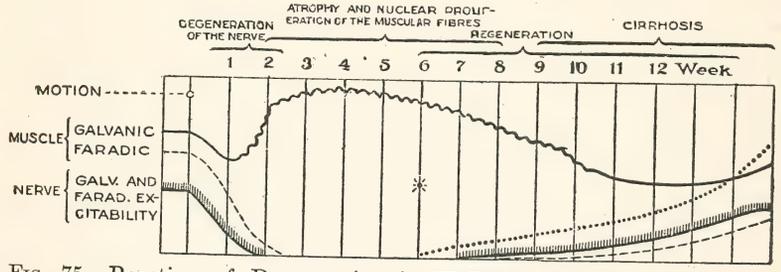


FIG. 75.—Reaction of Degeneration in Wallerian Paralysis with Early Return of Motion. Return of volition motion indicated by star (Erb.)

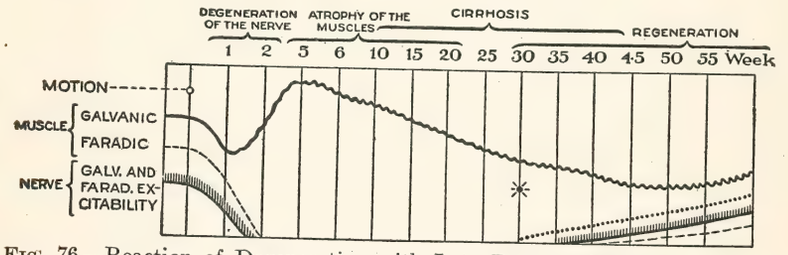


FIG. 76.—Reaction of Degeneration with Late Return of Motion. (Erb.)

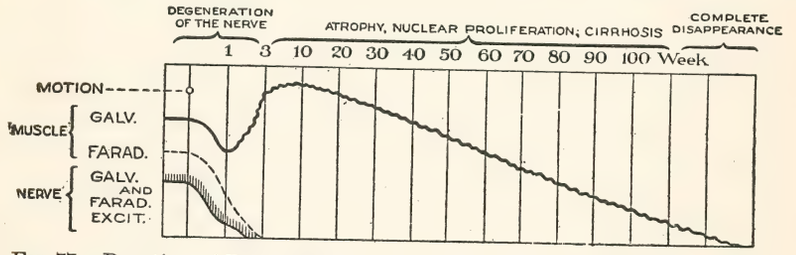


FIG. 77.—Reaction of Degeneration in Incurable Wallerian Paralysis. (Erb.)

sponse, while the faradic disappears, these changes in galvanic response corresponding with the initiation of histologic changes in the muscles themselves. Toward the end of this week a distinct increase of excitability to the galvanic current occurs, with a tendency to reversal of the normal formula. As expressed

simply this would be recorded as

CaCl < AnCl the normal being CaCl > AnCl

with the possibility of eliciting the AnO response with much less current than normally.

With this increase of irritability and *serial change* of formula a progressive change in the *mode* or quality of contraction occurs; instead of a normal, short, lightninglike contraction, slow, long-drawn, snakelike contraction occurs, which passes easily with a slight increase of current into a continuous tetanic contraction, lasting during the entire duration of the current, in spite of the fact that the current strength is insufficient to produce tetany in a normal muscle. This change is the most characteristic evidence of DeR.

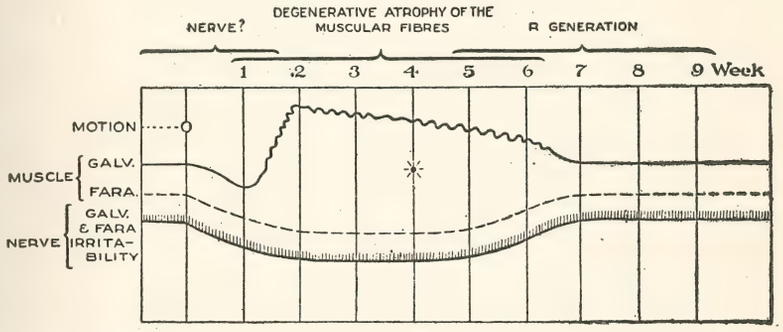


FIG. 78.—Reaction of Degeneration in Partial Wallerian Paralysis. (Erb.)

The diagrams, Figs. 75, 76, 77 and 78, reproduced from Erb, illustrate in a most excellent manner all the principal phenomena of DeR in typical cases of Wallerian paralysis with early return of motion; with late return of motion; in incurable cases and in those but slightly affected.

It will be seen that the comparison of responses elicited in a given case with similar conditions depicted in the diagram enables us to ascertain the approximate stage of the degeneration-regeneration process in the nerves and muscles, and permits of approximate prognoses. It is important to note, however, that all neurons and muscles affected are not necessarily at the same stage at a given time in progressive or continuing causations, hence the value of individual examinations of nerves and muscles.

It will be seen also from Figure 78 that partial Wallerian degeneration will furnish instances of partial DeR, only a part of the changes developing typically while the remainder are not developed at all or only in a rudimentary degree. In these instances the excitability of the nerves does not disappear but sinks to an often insignificant degree, although the changes in the galvanic excitability of the muscles are developed in a typical manner. Here the presence of the serial and modal changes in the muscle during certain weeks are, nevertheless, positive signs of traumatism or other efficient causation.

Since an affected muscle may react normally to both volition and *electrical stimulation through its nerve*, the presence of serial or modal change *when the muscle is directly stimulated* is most important in diagnosis and medical jurisprudence.

Recapitulation of the Objectives in an Examination for DeR.—The search for degeneration reaction and the recognition of its stage when found resolves itself, therefore, into:

1. The investigation of the presence of decreased excitability of nerve or muscle to the faradic current, as compared preferably with the corresponding nerve or muscle on the opposite side in unilateral affections. When detected in either situation it is suggestive of DeR but not conclusive unless the history assists in the determination. Moreover, the failure to obtain response is negative evidence only, and may be due to a poorly acting apparatus or faulty technic, or to too great a layer of insulating adipose tissue between the electrode and the point examined.

2. The eliciting of a quantitative increase in the galvanic excitability of a muscle on direct stimulation is distinct evidence of DeR, but requires that we should know the normal number of milliamperes required to obtain the minimal response in that muscle in that individual, for this will vary normally with the thickness of adipose insulating tissues overlying it and with the functional vigor of the muscle, being more easily elicited in the normal muscles of athletes, etc. When the injured or diseased part is unilateral we may readily compare it with the corresponding muscle on the opposite side of the body. A comparison with standard tables of the milliamperage required to elicit minimal responses in normal persons is less certain because of these variations of skin thickness, adipose tissue, etc.

3. The eliciting of a *serial change* in the response of a muscle, in which CaCl contraction is less for the same milliamperage than AnCl, is conclusive of the presence of degeneration, or even

when the closure contraction is the same for the two poles, which is a lessened amount of serial change but a serial change nevertheless.

4. But the most conclusive evidence of DeR is the *modal change*. The slow, wavelike contraction of a muscle affected with Wallerian degeneration is most characteristic and conclusive of the presence of DeR, and cannot readily be forgotten after being once observed.

5. Finally, in atrophic conditions of the muscle fibers with late sclerosis, we may have, at the end of many months, quantitative decrease of excitability alone in both muscle and nerve, or in the latter alone, as the sign of this stage of DeR.

Occurrence of DeR.—Degeneration reaction is certain evidence of Wallerian degeneration at or below the secondary motor center and of that alone. It is clear therefore that it will be present in all conditions in which the trophic influences are interfered with or destroyed at their source in the gray matter of the anterior horns of the cord or of the medulla oblongata, or in their conducting paths—the neuraxons of the motor nerves, in any portion of their course, inclusive of the motor roots; and, on the other hand, that it will not be found where the trophic centers and conductors have not been injured at all or so slightly as to permit disappearance of the reaction.

DeR may be found, therefore, at some time in the course of the following partial list of affections or injuries:

Inflammation affecting portions of the gray matter of the medulla oblongata which contain trophic centers, no matter what the causative germ. An instance is diphtheritic paralysis.

Chronic bulbar paralysis.

Acute and chronic myelitis affecting the gray matter, as poliomyelitis.

Hemorrhages into the cord involving the gray matter.

Amyotrophic muscular sclerosis.

Tumors destroying or injuring the anterior horns of the cord or pressing on motor nerves at any point.

Progressive muscular atrophy.

Certain aneurisms.

Neuritis from trauma or from infections.

Traumas. The DeR will be found in all injuries to trophic centers or trophic conductors in proportion to the degree of injury or destruction of the center or conductor. It will, therefore, be found in many

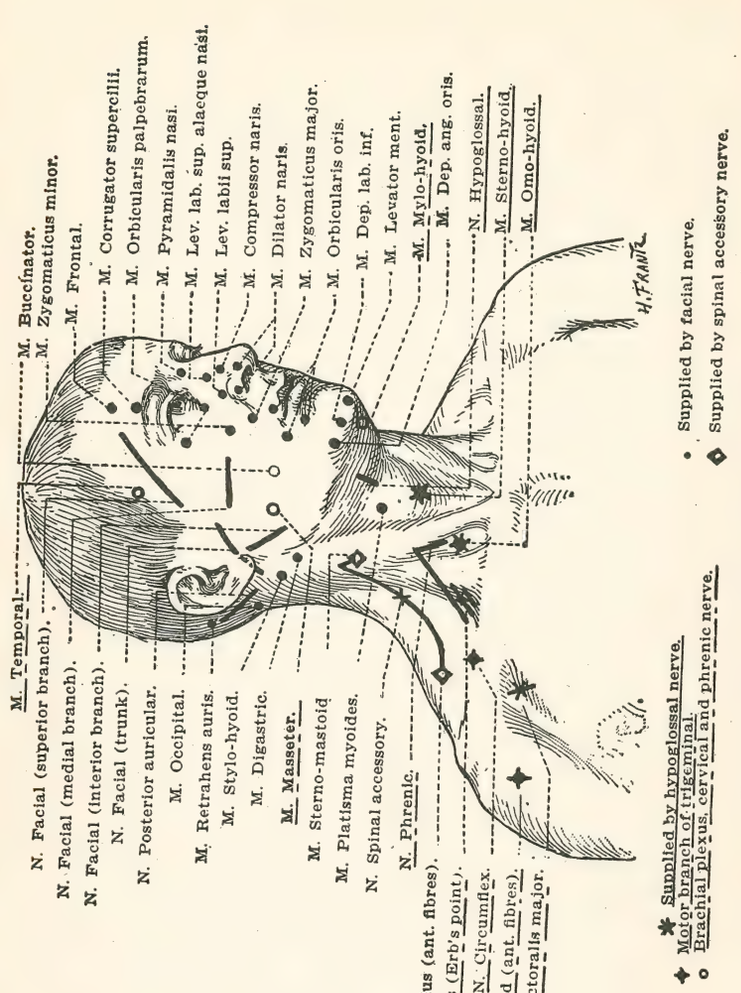


FIG. 79.—Motor Points of Face and Neck.

Spinal injuries, including concussion if severe.

Injuries to motor roots and motor nerves.

Compression paralyses, except when so mild that motor conduction alone is temporarily interrupted. These include paralysis from sleeping on the arm, tight bandages, tourniquets left on too long, poor crutches, retraction of scar tissue, formation of callus after fractures, etc.

DeR is never found in paralyses of cerebral origin arising, as most do, in lesions of the conducting paths above the gray nuclei of the medulla oblongata, or from lesions of the cerebral cortex. Any paralysis of the seventh nerve, for instance, in which it is absent is of cerebral origin and not peripheral. The importance of this test in prognosis of such cases is clearly evident.

DeR is absent in paralyses from diseases of the white columns of the cord, with the exception of the anterior root bundles.

DeR is never found in undoubted local and primary affections of the muscles, in atrophies from myositis and from joint diseases.

It is never found in hysterical paralyses.

It cannot be counterfeited by the malingerer.

Prognosis as Affected by the Presence of DeR.—In morbid conditions with a similar causation the prognosis in a given case in which DeR is found is the more serious in proportion to the completeness of the reaction and the more advanced stage in which it is found. Partial DeR is therefore more favorable than complete; the earlier stages more favorable than the late, for in the most favorable cases the later stages do not appear.

Thus three forms of rheumatic facial paralysis may be distinguished by the reactions corresponding with their severity and duration. If the electrical excitability is entirely normal (mild form), the prognosis is very favorable and the disease will last two or three weeks only; if partial DeR is present (middle form) the disease will continue about one or two months; but if complete DeR is present (severe form) the prognosis is relatively unfavorable and the paralysis will last three to nine months or longer.

The same is true of compression paralyses of traumatic origin, whether Wallerian degeneration is produced primarily at the time of reception of the wound or injury or is secondarily caused by contracting cicatrices or pressure from callus formation.

Failure to obtain DeR in a given case of apparent paralysis after the most careful examination is, of course, proof that no Wallerian degeneration is then present in the case, and may

mean, in conjunction with other indications, that the examined parts are either normal (malingering), or that the palsy present is cerebral in origin and not caused by trauma.

In sciatica the presence of partial DeR indicates a true neuritis, and the degree of the DeR present is a clear indication of the severity of the attack and the shorter or longer time that it will persist. Should the DeR be complete we may suspect a malignant growth within the pelvis as the cause of the pressure. The same is true of neuritis in other situations. The pain usually so prominent in pressure neuritis of mixed nerves is, of course, due to the inclusion of the sensory fibers in the morbid action.

In the case of a patient seen some years ago in association with the late S. Weir Mitchell, an unexplained severe neuralgia in the distribution of a portion of the brachial plexus showed partial DeR in the muscles of the arm, and was later cleared up by the emergence of a malignant growth between the second rib and the clavicle, the bony limitations to its growth on two sides causing pressure on the contiguous strands of the plexus.

EXAMINATION OF PARTICULAR NERVES AND MUSCLES

The detection of quantitative changes to the faradic wave is an easy task, and does not differ at the present time from the practice of the early clinicians in the middle quarters of the last century, except in the possibility that our electrotherapeutists no longer possess faradic apparatus. As stated elsewhere, we have no mechanical means of measuring these currents or of readily comparing the strengths of different batteries. Complete absence of response to this wave is, fortunately, the condition usually encountered when DeR is present, and this is, of course, readily ascertained in unilateral cases by comparison with the opposite side. Minor shades of diminution may be determined in the same way by using the current that produces the minimal contractions on the normal side.

Galvanic examinations, on the other hand, have been placed on a far more accurate basis since the time of the early writers. All doubt concerning errors due to changing resistances of the skin during the examination have been removed entirely by the use of the current controller, which permits us to adjust the resistance to permit any exact number of milliamperes to be used in any two positions for comparison of effects, regardless of differing resistances, and the milliampere has been adopted as

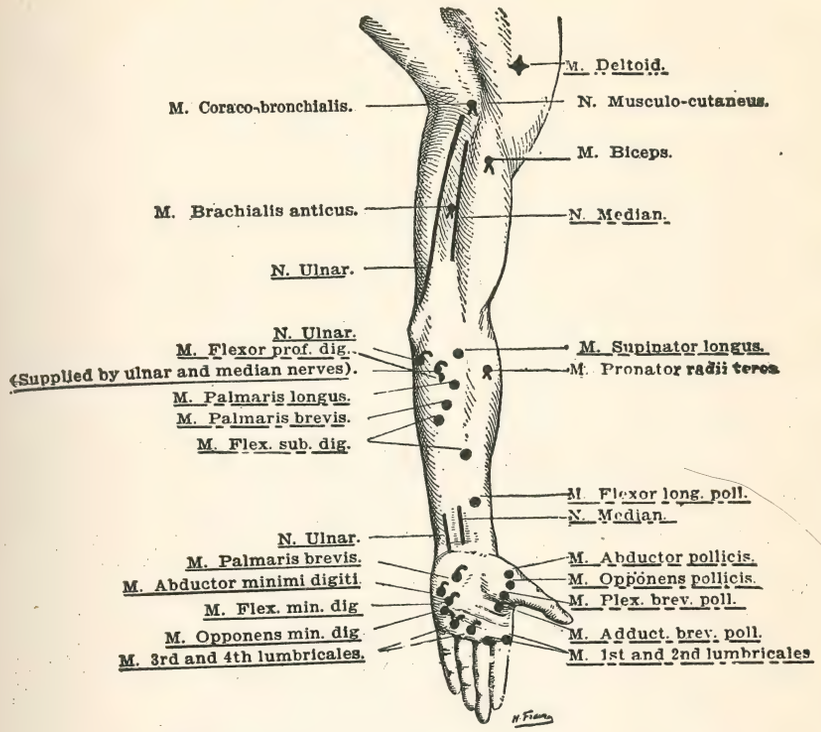


FIG. 80.—Motor Points of Front of Arm, Forearm and Hand.

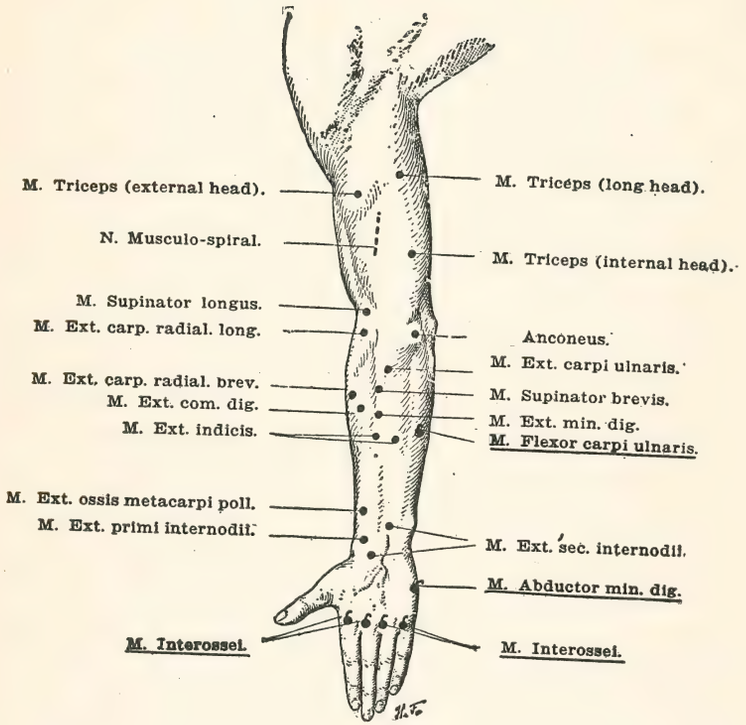


FIG. 81.—Motor Points of Back of Arm, Forearm and Hand.

a unit of current that permits of scientific accuracy and comparison of results attained anywhere in the world, regardless of the kind of generator producing the current. The difficulty of estimating the current actually traversing the ever-changing body resistance in the old days, when the number of cells used, or the deviation of the needle of a crude compass galvanometer without milliampere readings was the only means of measurement, should make us wonder at the accuracy of the clinical facts handed down to us.

The galvanic test is exceedingly accurate at the present time, and the meter readings of the milliamperage required, with a prescribed active electrode surface over the nerve or muscle point, may be accepted in judicial procedures as a mathematical measure of a natural law. This is true of both serial change and modal change, the former being reducible to figures and the latter to an ocular demonstration that are both readily made matters of evidence.

It is true, nevertheless, that the milliamperage required to move a given nerve or muscle in different normal individuals will vary with the depth of the adipose covering of the body, the leanest persons requiring the least current. This difference is, of course, bilateral, and is therefore unimportant in unilateral examinations, where the number of milliamperes required for minimal contraction of the nerve or muscle of the normal side are to be taken as the norm instead of the figures found in a table prepared from the averages of many tests of individuals. The following table of Stintzing is copied in this place as merely an example of the average milliamperage required to stimulate certain nerves at cathodal closure when the active electrode has a diameter of two centimeters:

STINTZING'S TABLE OF GALVANIC EXCITABILITY OF NERVES

I. THE MOST EXCITABLE GROUP

Requiring from 0.5 to 1 milliampere

N.	Musculocutaneous	0.05 to 0.28	average	0.17
	Eleventh	0.10 " 0.44	"	0.27
	Ulnar (above olecranon)	0.2 " 0.9	"	0.55

II. THE MIDDLE GROUP

Requiring from 1 to 2 milliamperes

N.	External popliteal	0.2 to 2	average	1.1
	Median	0.3 " 1.5	"	0.9
	Crural	0.4 " 1.7	"	1.05

III. THE LEAST EXCITABLE GROUP

Requiring from 2 to 2.5 milliamperes

N.	Internal popliteal	0.4 to 2.5	average	1.45
	Ulnar (at wrist)	0.6 " 2.6	"	1.6
	Musculospiral	0.9 " 2.7	"	1.8
	Facial	1. " 2.5	"	1.75

But it should not be overlooked that muscle tests are more important with the galvanic current than nerve tests, and that DeR is evidenced when AnCl requires the same or less current than CaCl, no matter what the actual amounts are, and that, except in the terminal stages of Wallerian degeneration, the modal change is its most characteristic evidence.

The following paper by Captain A. B. Hirsh, Medical Corps, U.S.A.,[1] is appended with Captain Hirsh's kind permission, to show the technic of condenser current testing in the army hospitals. It is evident that this constitutes a distinct advance in the accuracy of muscle testing.

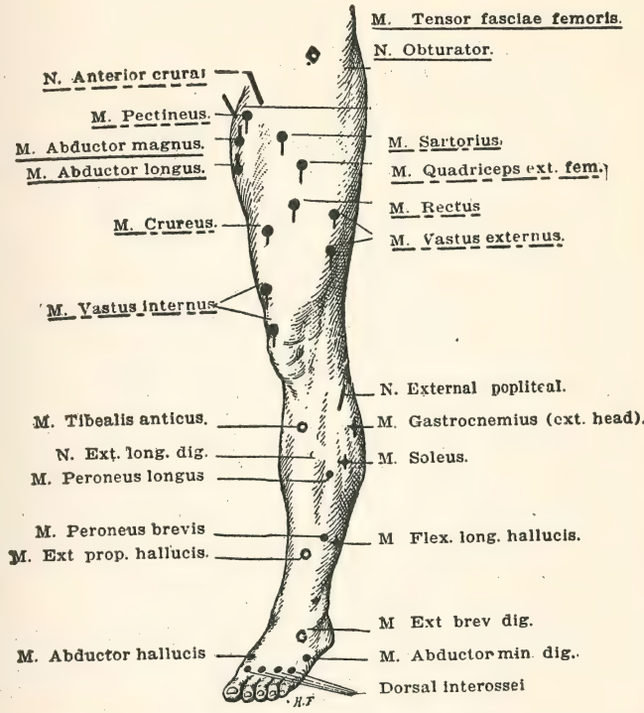
"Muscle and nerve testing at Walter Reed General Hospital has been largely carried out in its Department of Physio-Therapy, by arrangement with the other departments. The more accurate results from improved electrical methods employed—for the first time on so extensive a scale in the United States—warrant the summary here to be given. These changes have not been sufficiently stressed by the profession and are especially timely, in view of the extensive use to be made of these methods for industrial and various other injuries.

"THE GALVANIC CONDENSER

"The faradic and galvanic reverse-pole muscle and nerve test, so long in use, has, because of its merely approximate reactions, long been a source of study for betterment by physiologists and others. It is to the late Sir Lewis Jones that we are indebted for the first substantial advance in these examinations, as based on his galvanic condenser method of testing. This new condenser he held to be superior in results to the other interrupted or continuous currents by being speedier, more exact, less painful to the patient, and supplying more data in general. Hernaman Johnson has well described the technical basis for introduction into practice of the Jones condenser:

[1] *American Journal of Electrotherapeutics and Radiology,* February, 1920. Permission to print obtained from the Surgeon General of the Army.

Read at the annual meeting in Philadelphia, September 17, 1919, of the American Electrotherapeutic Association.



Sacral plexus; comprising tensor fasciae, femoris, gluteus medius and gluteus maximus.
Obturator nerve.
Supplied by anterior crural nerve.

o Supplied by sciatic nerve before its division into external and internal popliteal.
+ Internal popliteal passing into posterior tibial.
• External popliteal passing into anterior tibial and musculo-cutaneous.

FIG. 82.—Motor Points of Front of Thigh, Leg and Foot.

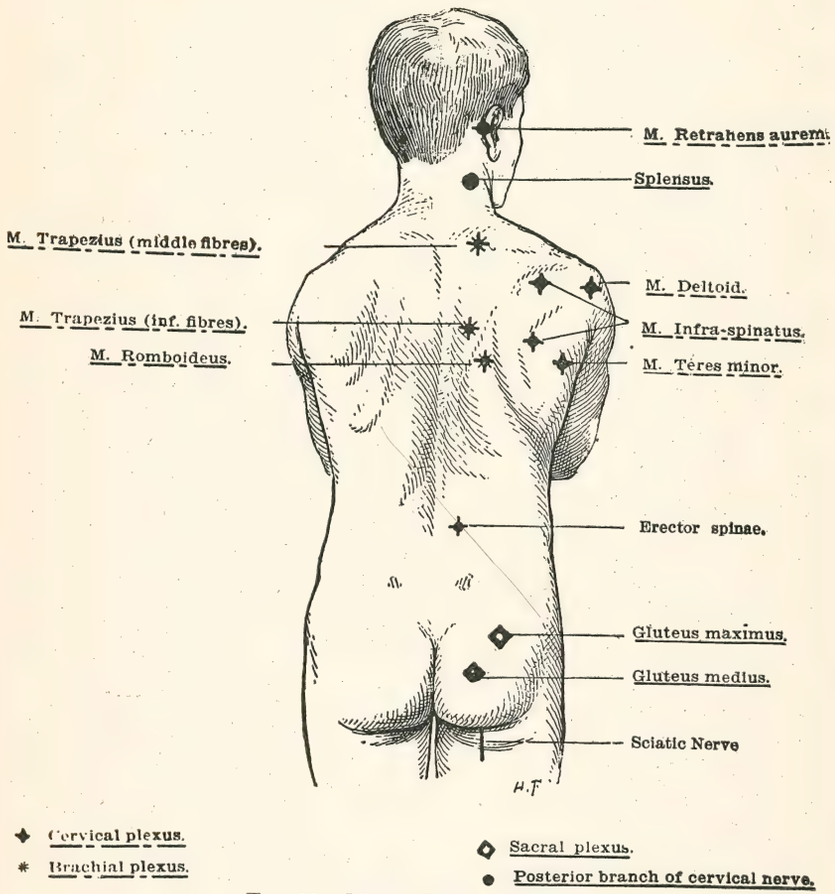
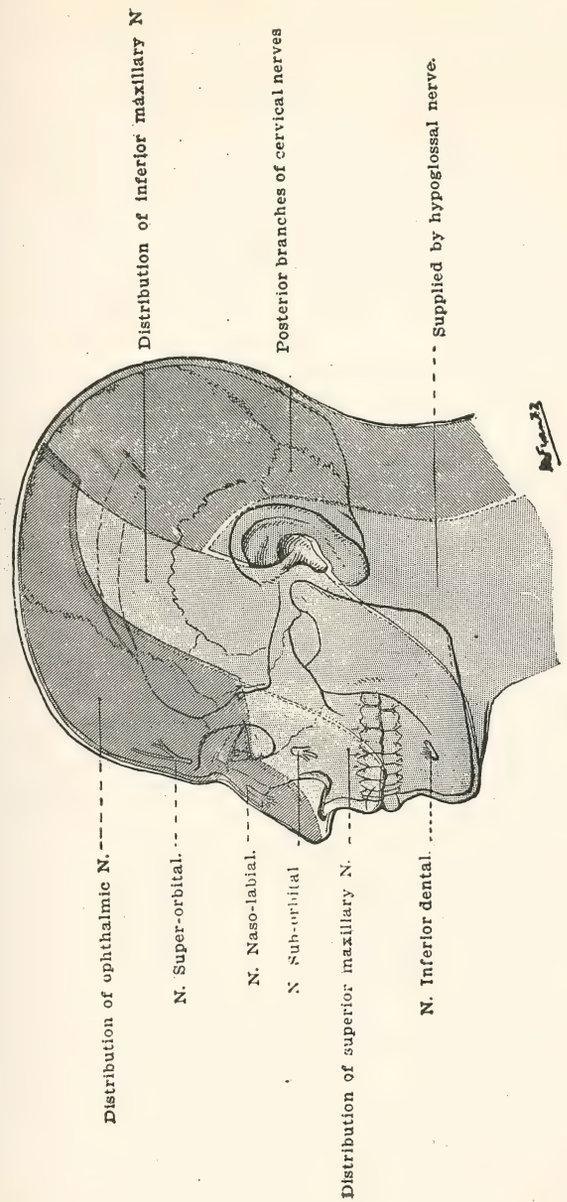


FIG. 83.—Motor Points of Back.



(After Testut.)

FIG. 84.—Nerve Supply of Face and Scalp.

"'A normal muscle is sensitive to stimuli of very short duration. An impulse lasting only 1-24,000 of a second, delivered at a potential of about 100 volts, is sufficient to cause a definite contraction in the muscles of the upper extremity. If, however, motor impulses are prevented for some days from reaching the muscles, a change occurs in their response. Impulses of longer and longer duration are required to excite them. In three weeks, a stimulus lasting 1-600 of a second may be needed; in six, 1-200 of a second may be insufficient. The average effective impulse

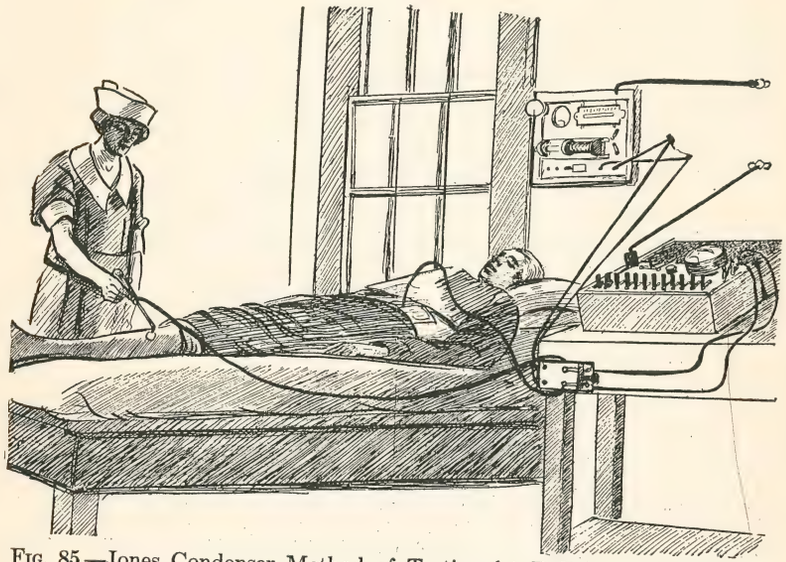


FIG. 85.—Jones Condenser Method of Testing for DeR. The faradic coil is seen on the wall and the condenser on the table.

from a faradic coil lasts approximately 1-1,000 of a second, and such a stimulus ceases to be effective in about ten days. A muscle which no longer reacts to faradism has been said to show "reaction of degeneration." If, however, a muscle which has just ceased to respond to a given length of impulse be stimulated by an impulse of the same duration *delivered at a higher voltage*, contraction again occurs. The same phenomenon occurs if, voltage and impulse remaining constant, an increased number of impulses per second is discharged into the muscle.'[1]

"Because the ordinary faradic coil is not a standardized instrument as to impulse length, voltage and rate of interruption, Jones substituted the new current method just mentioned that provides for all the factors described. This able clinician and expert in electricity, by carrying a continuous current through a series of ten condensers of increasing microfarad capacity, practically reduced certain nerve and muscle tests to a simple matter of figures. The condensers in question ranged from 0.025 microfarad up to 3 microfarads, a pressure of about 100 volts being maintained to allow for a resistance of 1,000 ohms, the average throughout the body. He used a commutator and a metronome, the direct current from the main filling the condensers, for discharge through the patient's muscle. These condensers vary in their wave length or length of time for passage through the tissues. Normal muscle, for example, responds to the volume of current discharged from the smallest size condenser, 0.01 microfarad in the latest American model, in one or two-thousandths of a second, while degenerated muscle might require the largest condenser, 2 microfarads, or up to forty or sixty thousandths of a second in its passage.

[1] Francis Hernaman Johnson, in "Physical Remedies for Disabled Soldiers," William Wood & Co., New York, 1917.

"The original Lewis Jones instrument was improved by Francis Hernaman Johnson and later by the Department of Physiotherapy of the Surgeon General's office. The present American model, used in our war hospitals, has thus been simplified by doing away altogether with the metronome. It contains ten condensers with capacities ranging from 0.01 to 2 microfarads. These stand in a straight line along the front of the top of the portable case, each with its own switch-in-bar, the whole plugging into the direct current main. The voltmeter is placed behind the row of condensers, being controlled by a rotating switch alongside. The vertical spring bar, a light blow upon which discharges the condensers in circuit, is seen to the left of the volt dial.

"At the Walter Reed General Hospital, the usual routine provides for preliminary warming of the region to be tested; this may be done by radiant light and heat, by whirlpool bath or by diathermy. Care is also taken that the patient should not be tested when fatigued and that examination ceases before weariness ensues. The first step then is to obtain the muscle or nerve response to faradism, an instrument of the du Bois Reymond type being employed. The distance required by the secondary coil to cover the primary is marked in centimeters. Then, without lifting the active (negative) electrode from the motor point or nerve, a two-way switch is thrown, so as to turn on the condenser current. Starting with the smallest number, one condenser after the other, in ascending microfarad capacity, is turned on until distinct muscle contraction is noted. This required capacity

is then written in its proper column on the chart and a permanent record, seen at a glance, is obtained.

"Where, therefore, the ordinary interrupted or continuous currents failed to bring response in a degenerated muscle, the condenser has repeatedly proved its efficiency. Where the primary tests of defective muscles or nerves required high microfarad capacity, the following examinations, showing improvement under treatment, were carried out with condensers of smaller and smaller microfarad capacity until recovery was reached.

"Distortion of muscle groups may at times result from massive cicatrices, and then displacement of motor points makes proper electrical diagnosis a difficult problem. The experience of the Department proves that the condenser is of material aid in singling out the muscles thus drawn from their normal relationship.

"The whole range of war injuries and paralysis from incidental diseases are included among the cases thus tested at Walter Reed General Hospital. Of importance, numerically and otherwise, are the partly or fully healed wounds in which the results of the electrical response largely decide the state of the nerves supplying defective muscles. There may be incomplete or total nerve division or blocking. There may be involvement in more or less cicatricial tissue that needs immediate removal. Here arises the important question of operation, perhaps, with nerve suture, etc. Rarely does the condenser test fail to agree with the condition found at operation.

"The time limit assigned to this subject unfortunately precludes insertion into this report of such statistics and case histories as would have emphasized the value in practice of the bare facts here given. Enough has, however, been offered to show that the condenser is a valuable addition to the office of the electrotherapeutist and must have a constantly widening field of usefulness.

"THE PROGRESSIVE GALVANIC TEST [1]

"Reports continue to reach the United States of the growing resort in continental hospitals to a new method for testing degen-

[1] The writer is indebted to Dr. Tom A. Williams of Washington, just returned from duty in French hospitals, for perusal of the manuscript chapter of his prospective work on "Neurology in War Time," in which the method is described in detail. The Paris *Presse Medicale,* July 10, 1919, contains a paper on the subject by H. Laugier in which reference is made to other European investigators. J. Tinel ("Nerve Wounds," William Wood & Co., New York, 1918, pp. 53-59) shows that the new method had its origin in the research studies of the physiological laboratories, various authorities being quoted.

erated muscles. By the so-called 'progressive' galvanic current such weakened muscles are made to rhythmically contract without in any way stimulating such action in neighboring sound muscles or in powerful antagonists. The value of so great a change from or, rather, addition to established usage must be apparent to every electrotherapeutist.

"Special electrical apparatus, simple in design, is used to produce this effect which is based on an explanation of degenerated muscle action that also is as relatively original as novel. In complete RD, as is well known, under the galvanic current there is not only reverse-polar action and lessened excitability but also a demonstrable slowing of the contraction. This slow contraction in itself is what Tinel *(loc. cit.)* considers sufficient to characterize the RD. This hypo-excitability of the muscle is only apparent, however, resulting from the inexcitability of

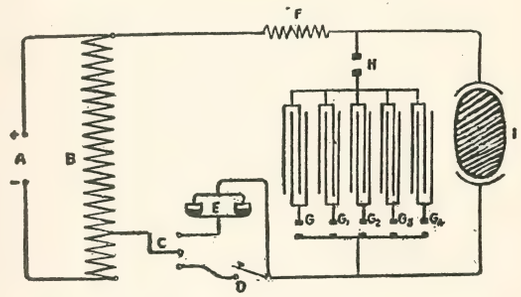


FIG. 86.—Schematic Plan of "Progressive" Method.

the motor nerve twig supplying it. Laboratory studies show that the degree of inexcitability of a muscle fiber is determined by what is called the *chronaxia,* that is, the interval before the muscle fibers respond to the stimulus, just as the flash point precedes the powder explosion. The example is cited that the muscle in the foot of a snail is a slow muscle, with high chronaxia, while the gastrocnemius in the frog is a rapid muscle with a slow chronaxia. If a very slowly increasing current is sent through these two muscles, the snail muscle will contract while the frog muscle will not. It is thus possible to apply the electric stimulus electively to the degenerated muscle fibers while keeping it below the threshold for the sound muscle fibers. If now a current is used that is sufficiently weak and can be contracted so as only very slowly to increase its strength, the degenerated muscles are acted on electively. Laugier, in the *Presse Medicale* article just referred to, describes the above mentioned special

apparatus, that of Lapicque, an outline illustration being included. This schematic plan is here reproduced with three other views of the apparatus, for which I also am indebted to Dr. Williams. Of these latter drawings, taken from his forthcoming work, the one depicts the patient under treatment with the instrument at hand; the others make plain how the condensers are slowly mechanically tilted into position while being brought into the circuit.

"The outline sketch shows the direct current from the main entering at A. B is a resistance switch control, either metallic

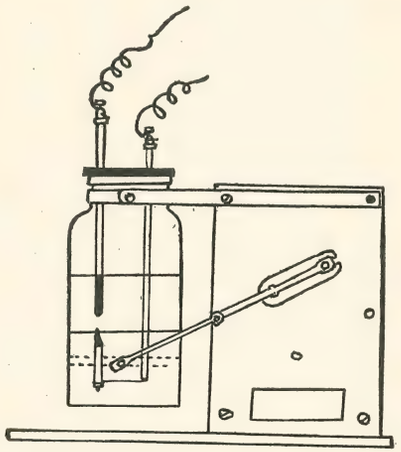


FIG. 87.—Mechanism for Tilting Condensers.

or liquid. C, a commutator with two binding posts, to utilize either one of two adjoining keys. D, the key for electrodiagnosis and E, that for the metronome for treatment. F is a resistance of 2,000 ohms through which the five condensers are charged the moment the circuit is closed. H is a mechanical interrupter at the point where the condensers are located. I shows the electrodes applied to the patient.

"The current is obtained by placing on the active electrode a capacity that may be varied at will. It is noted that the condensers in series with the electrodes are so arranged as to charge very slowly, retaining the current, so that the latter does not reach the electrodes in full strength until after these condensers have been fully charged; they can also be varied at will. Repeating, the current in the electrodes attains its

maximum terminal value only after having charged the condensers. One may vary the capacity introduced by correspondingly varying the rapidity of the current at the outset.

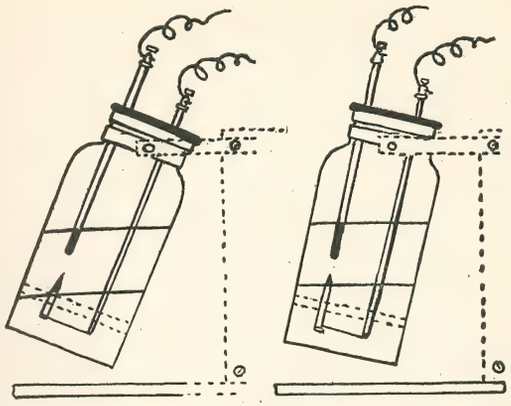


FIG. 88.—Mode of Tilting Condensers.

"Application of the new current is described as being easily grasped: the patient's extremity with the defective muscles is immersed in a glass or china container holding warm water,

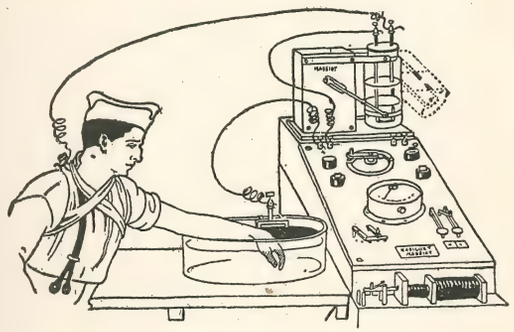


FIG. 89.—"Progressive" Method in Operation.

plain or weakly saline, in which also is placed the active electrode, the negative. The indifferent electrode rests on the neck or between the shoulders. When the interrupter H is open, the condensers are not in circuit, and only the unchanged continued current is obtained, with abrupt, prompt response; closing

the interrupter H, the condensers being in circuit, the operator utilizes their capacity (ranging from 1 to 50 microfarads) so that the current obtained starts from a minimum, then only gradually reaching its maximum after the condensers are finally fully charged. The ascending output of current is thus seen to be a very slowly progressive one. It is in this way that the degenerated fibers are contracted while those of the sound muscles fail to be acted on.

"When, by treating, one has thus found the suitable capacity and voltage to electively contract the degenerated muscles, using the switch D, it is only necessary to throw the switch at C over to E in order to obtain rhythmical contractions in these enfeebled muscles. By this technic it becomes possible to systematically exercise the latter without causing any contractions in neighboring healthy muscles or in the equally strong antagonists."

THE ELECTROLYTIC REMOVAL OF LEAD AND MERCURY FROM THE TISSUES IN CHRONIC METALLIC POISONING

Chronic poisoning among workers in industrial establishments producing or handling lead or mercury products is still encountered, in spite of hygienic precautions to lessen the inhalation or ingestion of the metal or metal salts, the ingestion, from eating lunch without previously washing the hands being thought the chief means of body access.

Baths for elimination under direct current power have been installed and are used, the method of course being a mere reversal of the ionization procedures described in Chapter V. It should be a reasonably effective process if properly carried out, for, by a calculation similar to those shown in the table on page 44 it will be found that 100 milliamperes of current will transport 736 milligrames of lead in an hour, or 620 milligrams of mercury in an hour, *if there were no other cations in the body to be moved.* As there are many other cations in the body tissues and fluids besides the poisonous cations, no such amounts of lead or mercury can, of course, be forced out by this current in this time. Yet it is evident that prolonged and repeated applications of 200 to 500 milliamperes will withdraw material quantities of these ions in time, particularly as lead and mercury are apt to remain in the body as ions rather than as metals. This is less true of silver, and attempts to remove silver deposits from the tissues will doubtless be less successful.

The bath usually recommended has been the bipolar bath, in which a rubber diaphragm extends across the middle of the bath in such a manner as to clasp the patient tightly around the waist, the cathode being in one compartment and the anode in the other. This diaphragm is apt to be troublesome to keep water tight; moreover, most of the action is at the edge of the diaphragm on both sides and not distributed as evenly as desirable over the body surface.

A better method is the use of a half bath as the eliminating cathode and a large kaolin pad as the anode. This is arranged as follows: The patient lies in a porcelain or wooden tub (unconnected with plumbing pipes), and sufficient 2 per cent. warm solution of sodium chlorid is poured into the tub to immerse the body to a point but little above the middle of the patient's body. Four metal plates of any metal are placed in the solution, one at each corner of the tub as far from the body as possible, and are connected with the cathode binding post. On the middle of the abdomen and epigastric region a large kaolin pad is placed with aluminum plate connected with the anode. This pad should be well away from the water edge.

When the current is gradually turned on the effect will be to drive the metal cations from that part of the body beneath the anodic pad into the outer parts of the submerged portion of the body, and ultimately outside the body into the salt water, while the chlorin ions will enter the skin of the submerged portion and facilitate the ionization. The position of the body may be changed at subsequent applications, unless indeed we wish, first of all, to drive the metal from a particular region first, when this region should be under the anodic pad for some time.

Whether some cation might not be added to the water of the anodic pad to facilitate the dispersion of the metal cations beneath it may be a question for an expert bio-electrochemist to determine.

With the skin in good condition, a current of 200 to 500 milliamperes may be passed through such a bath with only moderate discomfort.

CHAPTER XII

ELECTRICITY IN ONCOLOGY

Electrothermic Destruction of Localized Cancerous Growths—Electrocoagulation with the Low Voltage Direct Current—Historical Notes—Indications for Electrocoagulation of Malignant Growths—Unipolar Zinc Ionization in Small Epitheliomas—Minor Operation of Electrocoagulation with Low Voltage Direct Current—Major Operation of Electrocoagulation with Low Voltage Direct Current—Operations on the Face and Scalp—Operations on the Eyelids—Operations on the Lips and Neck—Operations on the Nose and Within Nasal Cavities—Operations Within the Mouth and on the Tongue—Operations on the Breast and Axilla—Operations on the Neck of the Uterus—Operations on the Rectal and Anal Regions—Operations on Malignant Growths in Miscellaneous Situations—Surgical Diathermy with High Frequency Currents—Historical Notes—Electrodesiccation—High Frequency Cauterization—Electrocoagulation with the High Frequency Current—High Frequency Cauterization of Bladder Tumors.

THE ELECTROTHERMIC DESTRUCTION OF LOCALIZED CANCEROUS GROWTHS

I. ELECTROCOAGULATION WITH THE LOW VOLTAGE DIRECT CURRENT

Historical Notes.—The destruction of cancerous and sarcomatous growths by massive, concentrated diffusion of zinc ions and high temperature had an early history in which the ionization alone was thought to be the only effective agency of the method, which employed the mercury ion in conjunction with the zinc ion in unipolar applications. The earliest publication of the author's original work along this line was March 9, 1895,[1]

[1] The author's publications prior to 1904 were as follows:
"Local Electrolysis and Zinc-Amalgam Cataphoresis in Malignant and Non-Malignant Tumors," *Medical News,* March 9, 1895.
"The Treatment of Hemorrhagic Conditions of the Uterus by Zinc-Amalgam Cataphoresis," *Journal of the American Medical Association,* August 24, 1895.
"Zinc-Amalgam Cataphoresis in Muco-purulent Inflammations and Malignant Growths," Philadelphia Polyclinic, October 19, 1895.
"On a New Treatment of Sarcoma," *American Medico-Surgical Bulletin,* June 27, 1896.
"The Treatment of Cancer by a New Method, viz.: the Electrical Diffusion of Nascent Oxychlorides of Mercury and Zinc," *Medical Record,* July 31, 1897.
"On the Radical Cure of Malignant Disease by the Cataphoric Diffusion of Mercury from Gold Electrodes, with details of Late Improvements in the Author's Method," *Philadelphia Medical Journal,* March 19, 1898.
Chapter on the Treatment of Malignant Disease in "Conservative Gynecology and Electro-Therapeutics," The F. Davis Co., Philadelphia, 1898.
"The Cataphoric Treatment of Cancer." *Transactions of the American Electrotherapeutic Association for the year 1900.*
"Cases of Carcinoma and Sarcoma Recently Treated by Electric Sterilization." *Transactions of the Philadelphia Co. Medical Society,* 1902.
"The Destruction of Cancerous Growths and Sterilization of the Surrounding Tissues by Mercuric Cataphoresis." *International Medical Magazine,* November, 1902.
"The Treatment of Carcinoma of the Rectum by Mercuric Cataphoresis." *Journal of Advanced Therapeutics,* May, 1903.
Also, by Dr. Amedee Granger, of New Orleans: "The Treatment of Cancer by Mercuric Cataphoresis," *New Orleans Medical and Surgical Journal,* Dec., 1903.
[1] "Ionic Surgery in the Treatment of Cancer, with a Chapter on Ionization in Surgical Tuberculosis and in Hemorrhoids," A. L. Chatterton Co., New York, 1910.

followed by numerous papers at various times, and by a monograph in 1910.[1]

After experiment with various ions, including the pure mercury ion from gold electrodes, and the arsenicum ion, the zinc ion was finally demonstrated to be the most effective for electrochemical destruction of malignant growths, both of itself in small epitheliomas and associated with electrothermy in large malignant growths; it being found while treating a recurrent cancer of the breast at the Howard Hospital in 1896 with bipolar electrodes that increasing the current to 1000 milliamperes caused sufficient heat to develop between the opposite poles to add materially to the quickness of the devitalization.

In the further development of electrocoagulation operations for cancer at the Oncologic Hospital in Philadelphia the bipolar method (with both poles in the growth) was used more largely after 1906, but the value of the heat element was not appreciated until the author witnessed a demonstration of electrocoagulation

by the d'Arsonval current given by the late Dr. Doyen, in Paris in 1910. Since this date the heat developed between the poles of the more conveniently applied direct current electrocoagulation operations has been fully utilized by increasing the amperage of the current and employing the strict bipolar method instead of the unipolar in all large growths.

Indications for Electrocoagulation in Malignant Growths.—The purpose in view in all ionic and thermic operations on cancer is the immediate devitalization of the cancer-bearing tissue, *in situ,* inclusive of all infected edges, the method coagulating, devitalizing, and sterilizing protoplasm, blood and other tissues, including microörganisms of every kind, without loss of blood other than that contained in the growth, and leaving a sterile crust surrounded by healthy tissues from which it subsequently separates by the formation of a line of demarcation. By the nature of the process, all vessels and lymphatics are sealed at the line at which coagulation ceases, rendering the operation bloodless and preventing absorption of deleterious matter by the system. A similar action on sensory nerve filaments tends to lessen postoperative pain.

The chief objects of this operation or application may be enumerated as follows: By the devitalization of the cancer cells *in situ,* to prevent operative reinfection; to reach the peripheries of a malignant growth safely by carrying a destructive force through its substance, and thus save surrounding tissue while destroying the whole of that infected; to reach the peripheries of malignant growths that are situated within cavities *by carrying the surgical force through the natural openings,* the electrodes carrying the power being slender and capable of being bent at any angle needed to reach the site of the disease; to operate on a malignant growth within a cavity with the ease of a curettage, yet doing a bloodless operation that cannot reimplant the disease; to save the blood otherwise lost in dissecting operations; to shorten the time of the patient under general anesthesia, when this is employed; and to save normal tissue while obtaining as good or better results than was formerly possible.

Both zinc ionization in small epitheliomas and electrocoagulation with the direct current in larger growths are presented in this chapter as methods of election in appropriate cases and not as exclusive methods. The minor method is probably the most scientific process possible for the autoselective diffusion of lethal chemicals to infected cells to the exclusion of normal cells, so

far as autoselection is possible, the autoselection being in this case based on the fact that cancer cells are usually a better conductor of electricity than normal cells, and therefore more power will traverse them if there is a choice of conductors in its path. But the minor, unipolar method will require too much time if applied to a large growth, with the patient under general anesthesia; hence in such cases it is replaced by the quicker bipolar method, in which everything between the poles is impregnated with the chemical and brought to a boiling temperature, both the healthy cells and the unhealthy cells. The unipolar zinc ionization is merely an application or minor operation, while electrocoagulation is either a minor or major operative procedure in accordance with the size or the location of the growth, a small carcinoma on the dorsum or tip of the tongue, for instance, being necessarily a major operation on account of the pain that would attend its eradication under local anesthesia, as well as the extreme need of complete and free extirpation of a malignant growth in this location.

The employment of either method with the expectation of securing a complete eradication of a malignant growth is predicated, of course, on the accuracy of the diagnosis that the case is still in the stage of local infection only, or with infected regional glands capable of being destroyed by the bipolar method at the same operation; in other words, that it is operable by older methods, or nearly so. It may be employed, however, as a palliative in more advanced cases, in the removal of ulcerated and hemorrhagic original growths in the presence of probable metastasis or of too general glandular infection for eradication of the latter.

Electrocoagulation may be employed in conjunction with other methods, as, for instance, in destroying a malignant growth of the bladder through a suprapubic opening made by the knife; or in preparing cases for further treatment with the X-ray or radium.

Unipolar Zinc Ionization in Small Epitheliomas.—The unipolar method of zinc ionization was the only method employed by the author and colleagues using zinc ionization between 1893 and 1897 and the principal method between the latter date and 1906, being usually described in journal articles and works on electrotherapeutics as zinc-mercury cataphoresis. The use of mercury as an amalgamated covering of the zinc electrode, and therefore as an ion in the treatment, was later abandoned as

unnecessary in destructive ionizations of cancer with the zinc ion. Experiments with the pure mercury ion (driven into the tissues from gold electrodes with which it was amalgamated, the gold not being ionized), showed the mercury ion to be less destructive of tissue than the zinc ion alone. An equally important reason for using the plain zinc needles was their brittleness when coated or amalgamated with mercury. It was impossible to do fine work in directing the flow of ions by placing the electrodes in proper spots, particularly in small growths.

The result has been a total abandonment of the mercury ion by the author except in nonmalignant conditions, where we wish a maximum of sterilization with a minimum of destruction of tissue. It was the author's original practice to leave the crusts of large devitalized growths in place until they separated as a slough, and with such a practice there is no doubt that the mercury ion, intimately united with the anions of the protoplasm of the dead tissue, prevented the development of odors during the process of separation. Some years ago Dr. John W. Swan kindly tested bacteriologically the mass remaining after zinc-mercury ionization of a large breast carcinoma that had been deeply ulcerated and the seat of a purulent discharge. The crust was found to be sterile immediately after the operation (with no preoperative preparation), and it remained sterile for twelve days.

But it was later found to be unnecessary to leave these large dead masses to be removed by separation, and they are now clipped away with scissors immediately after the operation, confining the cutting to the dead tissue alone, of which a layer one or two centimeters thick is left above the living tissues. This is not only of esthetic value in removing a sense of weight and lessening the odor during the separation, but permits of immediate inspection of the lower layers of the devitalized growth before allowing the patient to emerge from the anesthetic, and a reapplication if necessary.

With abandonment of the unipolar method in large cancers and sarcomas in favor of the bipolar method and thermic effects, it has been found wise, when not employing the less troublesome desiccation with the Oudin high frequency current, page 267, to continue the use of the unipolar method in small epitheliomas —those too small for both poles to be used without unnecessary inclusion of surrounding skin in the destruction; and in these small skin growths full reliance can be placed on the zinc ion

alone without pushing the current power to the point of obtaining thermic effects.

The unipolar method of zinc ion destruction is efficient in epitheliomas of the skin from the size of a dime down, but the bipolar method is more efficient in all larger growths of the surface and in all growths within cavities. An important factor in the problem of choosing between the two methods is the urgent

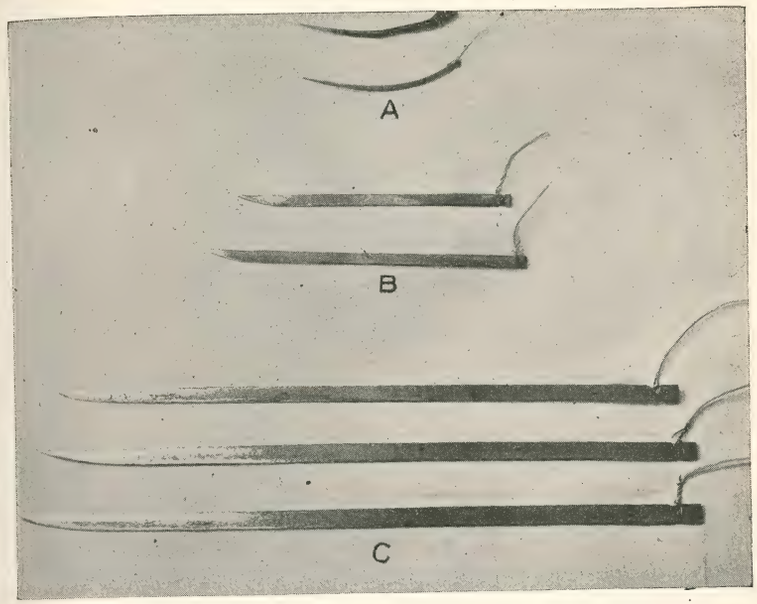


FIG. 90.—Zinc Anodes for Direct Current Coagulation of External Growths. A, smallest size, the upper anode being insulated. B, anodes for medium sized growths. C, anodes for the largest growths. (One-half natural size.)

need for selecting that one which, with other advantages, promises complete destruction of the growth at one application. The author's experience with piecemeal destruction has made him an advocate of complete destruction at one operation. One should never wound a cancer until prepared to overwhelm it. Too many colleagues essaying to use this method have reproduced these earlier errors, with results far inferior to those attainable by quick, thorough bipolar destruction.

Technic of Unipolar Zinc Ionization of Small Skin Epithe-

liomas.—The operator, having a direct current supply and controlling apparatus that will permit from 5 to 25 milliamperes to be turned on without irregularity or sudden increment of power (Chapter III), with meter reading in no larger spacing than single milliamperes, will need but the simple zinc needles, fine conducting wire and a broad dispersing pad for this application.

The Active Electrodes.—A sufficient number of zinc needles are cut with long handled, short bladed surgical scissors, or with tinners' shears, from the thin sheet of commercial zinc plate sold as one-sixty-fourth of an inch thick (about two-thirds of a millimeter), of a length varying from 1¼ inches to 2 inches according to the size of the growth, and of a width only sufficient to ensure rigidity with least weight. The best shape is the unequal sided triangle with very sharp point shown in the upper part of Fig. 90, this shape securing rigidity in the middle where it is grasped, a very sharp point at the active end and light weight at the attachment end. From 4 to 6 needles are prepared for the average small growth. Before attaching them to the conducting wires they are sharpened to fine points with a fine-cut file on a hard wood block, the filing motion being towards the points of the needles.

The wire should be no heavier than No. 34 or No. 36 Brown & Sharpe gauge, double cotton covered, this fineness being essential in order that the needles will not be dragged out of place by the attached conductors. For six needles, three wires should be cut from the spool twice the needed length, and the insulation removed from a small spot at their middles by shaving with a sharp knife. The three wires are then doubled at the bare spot to make a leash of six wires, and they are twisted together at the junction for a single attachment to the anode binding post. The free end of each wire is then bared in the same way by shaving the insulation.

The electrodes are now attached to the conductors by winding the bared wire end about the shank of the electrode and bending the end of the latter over the wire with a pair of small pliers. The wires should be attached to the electrodes firmly, so that no motion can occur to cause shock, but the clamping must not be too vigorous else the wire may be weakened and break during movements of the patient.

The construction of these electrodes is thus minutely described as they must be prepared by the operator or an assistant before each application, since they are rarely used more than once. It has been impracticable to have them made by instrument makers, largely because of their cheapness and simplicity, and possibly also because the shape and size of the needles have varied in the development of the method, and will vary somewhat with the size and position of the growth to be treated.

Commercial zinc plate, though containing ferric impurities that remain on the instrument as a dark rust after use, is the only practicable material from which the needles may be fashioned, being readily procured at stove dealers and easily cut with the scissors or shears described.

Dr. C. R. Dickson, of Toronto, Canada, experimented with pure, electrolytically deposited zinc some years ago, while mercury was still employed as an additional ion on the zinc electrode, but found the pure zinc was brittle and hard to amalgamate.

Dr. F. Howard Humphris, of London, England, presented the author with specimens of zinc wire that were readily shaped into small electrodes, but were less rigid than those made of the plate. Zinc wire, moreover, is difficult to obtain in this country.

The Dispersing Pad.—Any efficient water-holding dispersing pad may be used as the indifferent pole, preferably the kaolin pad described at page 21.

The Application.—With the patient reclining on the operating table, the dispersing pad is placed beneath the back or on the abdomen and its conducting wire attached to the cathode or negative binding post of the apparatus. The leash of wires attached to the active electrodes are now guyed to the skin of the patient near the growth by attaching a strip of adhesive plaster to the wires about three inches back of the electrodes and then to the skin, in such a way that the wires will not come into contact with the skin and will be held firmly at that point, permitting motion of the patient without strain on or disarrangement of the electrodes themselves (since movement of the electrodes during treatment adds to the pain). With their conducting wires attached to the anode or positive binding post, the electrodes are inserted into the growth, one after the other, before the current is turned on. The insertion is preferably *into the substance of the epithelioma* rather than into the surrounding flesh or beneath it, as is done in the bipolar method, as the growth itself is quite insensitive, each needle being inserted near the middle of the growth with its point towards a periphery, thus all portions of the small growth will receive the ions simul-

taneously and the pain of adding a needle while the current is on is avoided. This mode of placement permits the ions themselves to reach the edges of the growth, the white color produced giving us excellent notice of the inclusion of all possibly diseased tissue in the ionization. The unipolar method is rather more conservative of tissue than the bipolar, a fact to be considered in epithelioma of the face for cosmetic reasons.

The current is turned on very slowly until the patient feels a burning sensation. This may be at 2 or 3 milliamperes. To render further increase less painful a drop of a strong solution of cocain or any of its synthetic imitations is now placed on the growth so that it will flow around the needle insertions, the solution seeping into the epithelioma alongside the needle and the anesthetic ions being carried further into the tissue by the current itself with the zinc ions. This may be termed *phoretic anesthesia.* Several minutes later the power may be slowly increased to 7, or even 10 ma., and in larger growths to as much as 15 or 20 ma. without undue pain.

As the ionization proceeds, areas of white discoloration will surround each electrode, very readily seen unless a drop of blood has been drawn, when, for a time, the dark colored ionized hemoglobin will conceal the tissue whiteness. The action should be continued until the whole of the growth is whitened, this effect being carried a little beyond the apparent peripheries. This will usually require a half hour, or possibly longer. *No epithelioma should be attacked in this unipolar manner that cannot be ionized in one application.* Growths too large for this should be placed under the bipolar method with local anesthesia by endermic injection, as the elimination of pain by the injections removes the limitations on increased power, with correspondingly quick and thorough results.

After all portions of the small growth have changed color and become flat, with sufficient extension of these results to all peripheries, the current is turned off, the electrode is removed and a dry dressing applied, held in place by zinc oxid adhesive strips.

After Treatment.—In forty-eight hours there will be noticed some serous discharge, and in several days the beginning of the formation of a line of demarcation between the crust and the healthy tissues. At this time the part should be dressed with an ointment made of 1 part zinc oxid ointment and 10 parts of amber petrolatum, this dressing being renewed daily until the slough comes away, the dressing to be continued daily during

the filling of the wound by granulation and its cicatrization.

A granulating wound treated by an ointment in this manner needs no cleansing of the granulating surface when removing the dressing, only the surrounding skin being cleansed, preferably with soap solution followed by a little gasoline on a cotton swab. Epidermization of such a wound so dressed is prompt and complete, with surprisingly little scarring or deformity.

Minor Operation of Electrocoagulation with Low Voltage Direct Current.—With skin growths larger than a dime; having raised and probably sensitive bases of ill-defined extent; in growths of any size where the patient cannot receive general anesthesia; or in specially sensitive situations, yet too small for general anesthesia, the proper method is the minor bipolar operation with well applied local anesthesia. There is, nevertheless, a slight disadvantage in the endermic anesthesia that renders the unipolar method described above or the electrodesiccation method, page 267, a distinct advantage in small basal celled epitheliomas, and this is that the swelling of the skin after endermic injections near a small growth of the face, for instance, makes it more difficult to determine the exact limits of the growth, and compels us to sacrifice more tissue.

Local Anesthesia.—For local endermic and nerve-blocking anesthesia the author has employed procain, apothesin and quinin-and-urea-hydrochlorid at different times, the two former more recently. A 2 per cent. solution is injected endermically in a concentric circle about the growth from one-half inch to an inch from its outer edges. If the second insertion of the hypodermic needle be made in the blanched wheal made by the first injection into the substance of the skin, the third in that produced by the second, and so on around the growth to the point of beginning, but little pain will be caused by the injections. Sensory nerve branches included in the circle may now be reached by deeper puncture and their function "blocked" by an injection.

Active Electrodes.—The zinc needles for all bipolar operations are inserted beyond the periphery of the growth, pointing radially to its center, and should usually be long enough and rigid enough to reach near that point. For the smaller growths they may be cut from the thin zinc plate mentioned above. When they should be longer than 2 inches the one-thirty-second inch plate is preferable. This is the thickness of zinc plate from which small white metal signs are made, and may be cut by tinners' shears to a shape similar to the minor electrodes de-

scribed except that, being more rigid, the bulge in the middle is not necessary (Fig. 90). They are prepared in sheaves of six for convenient handling and connected with No. 30 wire in the manner already described, except that the wire is wound around a narrowed neck near the butt end made by a file and the wire twisted tightly. They should be filed to a long fine point. From 6 to 12 or more should be prepared, according to the size of the growth, and they should be no longer nor heavier than necessary for the particular growth.

The Indifferent Cathode.—In all bipolar operations the indifferent cathode is placed in the center of the growth, and is

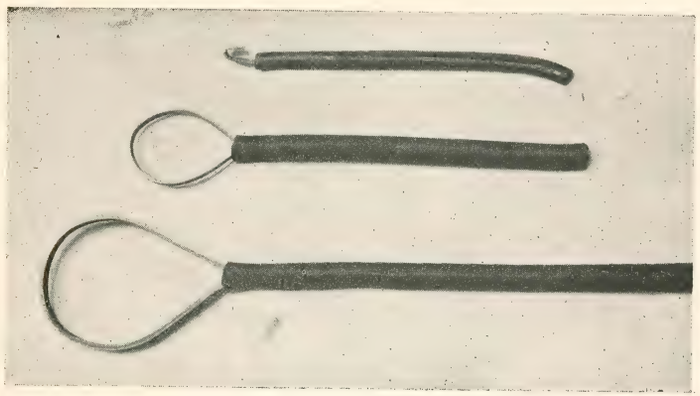


FIG. 91.—Cathodes for Direct Current Coagulation of External Growths. Conducting wires, not shown in figure, extend from shanks, and are covered with rubber tubing.

made self-retaining more or less when the space is sufficient, or is held in place in smaller growths. They are made of zinc, except in breast operations, merely because they are easily fashioned of this metal from the strips of one-thirty-second inch or one-sixteenth inch plate that are used for the making of active electrodes. Such an electrode to be held by the surgeon against the middle of the growth is shown in Fig. 91, the contact point being curved for greater contact and roughened on its under surface to prevent slipping as the alkaline ions gather under it in action. All remaining portions of this cathode and all parts of its No. 28 or 26 wire conductor are slipped through a single piece of soft rubber tubing to prevent accidental contact of the wire with the active electrodes or the patient's person. Accidental short circuits between opposite poles produce shocks and muscular contractions, and, moreover, are likely to injure the apparatus; while contacts between unprotected wires and the patient are likely to cause burns.

Details of Minor Operation.—At the completion of the anesthetic injections the parts will be found comparatively painless and ready for the insertion of the zinc needles. These are

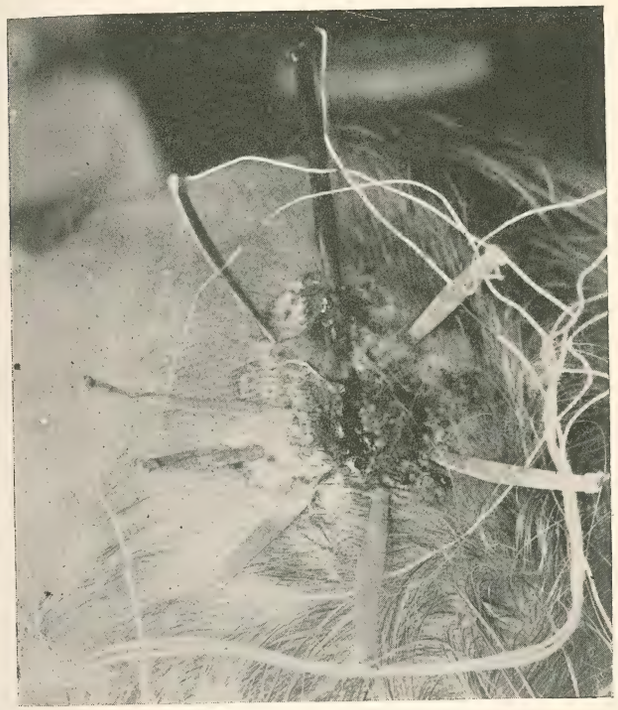


FIG. 92.—Illustration of Action of Zinc Ions in Bipolar Direct Current Coagulation of a Malignant Growth of the Scalp.

usually readily passed through the skin without previous puncture with a bistoury, being inserted in a slanting direction beneath the growth towards a point beneath the center, including enough of the healthy surrounding tissue to make sure that outlying prolongations of the cancer are included in the destructive process. In these minor applications a sufficient number of needles are inserted at once to surround the growth before the

current is turned on, the needles being about half an inch apart and all pointing towards the center.

With the cathode now held against the center, the power is turned on very gradually until the white effects are visible about each needle (Fig. 92), from 25 to 200 ma. being used according to the size of the growth and the remaining sensitiveness of the patient. If the sensory nerves have been imperfectly dulled by the anesthetic one must be content to make the application longer, in view of the fact that 25 ma. will do about the same work in half an hour as 50 ma. in fifteen minutes; though this relation of time and power is not absolutely interchangeable, since the presence of circulating fluids in the tissue and its power of self-adjustment to opposing force gives an advantage to bulk action in mass attack in contrast to the same action applied gradually over longer periods; and, moreover, one may obtain thermic effects by sufficient power in mass action even under local anesthesia.

Like all ionizations or electrocoagulations of cancer, the aim of the minor bipolar operation is to eradicate the neoplasm in one attack. Piecemeal methods of destroying cancer, once practiced by the author, are always to be avoided when possible, as the influence of a healing wound in tissue still cancerous is unquestionably stimulating to the undestroyed portion.

After Treatment.—The after treatment is the same as that specified after the unipolar application.

Major Operation of Electrocoagulation with Low Volt Direct Current.—The major operation must be varied in details to suit the special situation of the growth, and is therefore described more fully in later pages in its adaptation to each special part. The variations are chiefly adaptations to size, situation and the nature of the environing structures, and to a certain extent to its virulence, but are not due to differences in type or classification; for these methods of quick eradication may be used impartially for carcinomas or sarcomas if similar factors of operative indications are present. All tissues succumb alike to a sufficiently destructive heat, or to the massive replacement of the cations of the molecules of their protoplasm by the cations of zinc; and so far as we know, sarcoma cells are devitalized by the same degree of heat and chemical changes as carcinoma cells.

Preparation of the patient for operation should include the usual clinical investigations of the heart and lungs and of the kidney excretion to determine the wisdom of general anesthesia,

to which should be added a general inspection of the body for palpable gland enlargements, including palpation of the abdomen. If the growth is ulcerated the field of operation should be kept covered for some hours before operation by a cotton or gauze compress soaked in boric acid solution, *but no special efforts at sterilizing the field of operation by irritant antiseptics or by scrubbing should be allowed.* The author does not at present employ cathartics as a preparation for ether, relying on enemas alone when indicated.

The detailed directions given in preceding paragraphs apply in the main to major operations. All major operations have been bipolar in the author's practice in recent years, with greatly added efficiency.

Insulation of the patient from accidental contact with electrodes or wires is wisely secured by covering the patient with a rubber sheet on which electrodes may lie harmlessly when not in use, though connected with the active binding post.

General anesthesia is usually most convenient, though local anesthesia may often take its place. Since these operations rarely take more than forty minutes in the largest growths, many being done in twenty-five minutes or less, the objection to prolonged general anesthesia is eliminated. In most parts of the body there is added safety in the association of electric stimulation with the etherization also, a fact noticed by a number of skilled anesthetizers. To this statement, however, there are two important exceptions: the nearness of the heart to the site of application in the left breast and also the nearness of the pneumogastric nerve in growths of the neck. In both situations too powerful a current or its undue continuance, even when bipolar, is distinctly depressant and dangerous.

Active Electrodes.—The active electrodes for major operations on external growths are usually made from one-sixteenth inch plate strips, one-fourth of an inch wide and of lengths suitable to the case, and their conducting wires are of No. 30 wire. They may be arranged in sets of 6 electrodes each, and a most convenient device for assembling the combined ends of the wires to a single conductor attached to the anode binding post has been devised by Dr. Frederick C. Keck, of San Francisco, under the name of a multiple clip connector (Fig. 93). This device permits the addition of any number of electrodes during the operation without interfering with the action of those already inserted. Before proceeding with the operation this

multiple connector, with its cord extending to the anode binding post, is attached by its spring clasps to the sheet edge at the patient's side, being thus handy for the insertion into one of the clips of the twisted end of the wires of a set of electrodes (the latter resting meantime on a table alongside the operating table) before the electrodes are inserted in place, other electrode sets being added during the operation as needed.

In large growths it is well to use only enough electrodes to obtain chemical and thermic results in a given spot at once, the

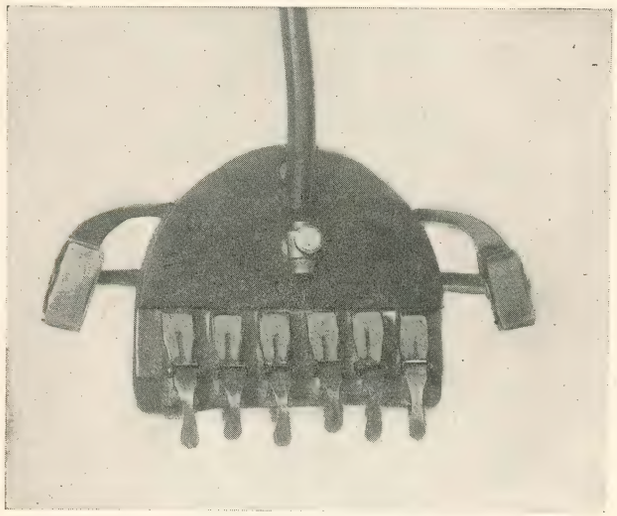


FIG. 93.—Multiple Connector for Anodes. This device is fastened to the rubber sheet covering the patient by the two lateral clamps, not in circuit. The six smaller clamps are in circuit, and permit the addition of sets of electrodes by their conducting wires as they are needed in the operation.

addition of new electrodes and removal of those that have served their turn being accompanied by so little irregularity of current action as to be neglible under anesthesia.

The Cathodes in Major Operations.—With 2 or 3 anodes inserted immediately beneath a segment of the growth a surface cathode (Fig. 91), or a self-retaining cathode (Figs. 120, 125), is placed on or inserted in the bulk of the growth near the electrodes and the power is turned on gradually until from 800 to 1000 ma. is in circuit. Other anodes are now added, and if the situation of the growth in relation to nearby vital parts permits,

the power is increased promptly but without suddenness to 2000 or 3000 milliamperes, when blanching and boiling effects vie with the zinc ion devitalization, great quantities of soapy froth having to be swabbed from the site of the cathode from time to time. As the destructive effects become sufficient at a given spot new anodes are inserted farther around and just beneath the circumference of the growth, those in the completed area being removed; and additional multiple cathodes are inserted also at times in new spots, the cathodes being all previously connected with the cathode binding post, until finally the whole circumference and under surface of the growth is devitalized, when the power is turned off, the electrodes removed and the dead tissue clipped away with a pair of scissors. This latter procedure permits a thorough exploration of the base of the growth, any living tissue found being promptly destroyed by a replacement of the electrodes in appropriate spots until the whole base is in a satisfactory condition. The cutting with the scissors is designed to be in devitalized tissue alone, or tissue that should be devitalized at once, thus leaving a half inch or more of devitalized tissue finally, carried into definitely healthy tissue.

Such an operation will require from ten to forty minutes of actual power use, according to the size and situation of the growth, the power being frequently turned off temporarily in cavities and other difficult places for inspection of results, the power changes being always made without shock.

Precautions to be taken when the growth is near vital parts will be discussed in the special descriptions of regional operations in succeeding pages.

After Care of Patient.—The after care of a patient subsequent to the typical electrocoagulation of a large external growth, as described above, is purely expectant during the first week, the wound being dressed daily with absorbent cotton or gauze after a thin layer of warm diluted zinc oxid ointment is poured over its surface, the whole being then covered with a binder. No special restrictions are imposed, the patient sitting up after the second day if her general condition has been good and the soreness of the parts permits.

During the second week a line of demarcation begins to appear between the devitalized tissues allowed to remain and the healthy tissues, accompanied by an increasing serous discharge which will necessitate two dressings during the 24 hours.

During the third week portions of the slough will become loosened, revealing living edges that will require a more liberal

application of the ointment. This ointment is composed of 1 part zinc oxide ointment and 9 parts of amber petrolatum, melted together in a water bath, and the purpose of its use is the protective covering of the healthy edges and bottom of the wound to exclude air, organisms and other irritants, enough being applied to prevent the contact of cotton or gauze with the raw wound, and later with the granulations. It has been the author's practice of late to have this ointment applied while quite warm, or even comfortably hot, the melted ointment being poured over the wound from a large spoon which itself is still warm from the hot water sterilizer. When so applied with due care as to temperature, the dressing becomes most comforting to the patient, the wound meantime having become painless after a few days. An abundance of absorbent cotton is placed over the ointment covered wound and a binder over all.

A dressing so applied comes away when removed in one piece, and after granulation begins an exceedingly clean wound is revealed at each dressing, a little serum alone bathing the surface, a large quantity of the latter having been absorbed by the cotton. *The wound itself should never be cleansed,* only the surrounding skin, and gasoline is an excellent material for the latter purpose if the skin is not too tender.

During the fourth and later weeks demanded for the healing of a surface wound the same régime is continued, with the difference that less ointment should be allowed to flow over the healthy surrounding skin, as it seems at times to be an irritant to skin, though protective only to the granulations.

A most helpful procedure during the period of separation and healing is the application of radiant light and heat to the bare wound, in the shape of a 25 watt incandescent lamp, with reflector, for 30 minutes at each dressing.

The time required for a large surface wound to heal by this open method of noninterference with granulation, from 6 to 8 weeks, is not a disadvantage. The wound is painless after the first few days, as has been stated, and this period of healing offers a valuable opportunity for daily inspection by sight and by touch to determine the possible escape of a portion of the cancer-infected tissue from destruction at the operation. This inspection is particularly valuable in the axilla, where an infected gland may have escaped destruction in the apex and be found lying loose during the third week.

Should doubtful tissue be recognized at any time it is promptly

destroyed as soon as identified (identification being made by a sensation of induration to the touch), the procedure to be employed now being the unipolar zinc ionization, with a set of small electrodes inserted into the doubtful tissue and a large dispersing pad elsewhere on the body. As all of the granulations, and particularly the unhealthy tissue, is at this time free from sensory nerves, it is deplorable not to destroy the doubtful tissue at once. As much as 100 to 150 ma. may be used for thirty minutes to an hour, without anesthesia, and at the cost of but little pain.

The author advises against postoperative radiation in these cases for the reason that he wishes to recognize remnants of disease if any exist before cicatrization has been accomplished. The X-ray is only used after ionization, or repeated ionizations show no hope of electrothermic eradication.

During the later weeks of the granulating process a healthy wound will show healthy granulations over its whole surface, regular in form and soft to the touch, free from odor, and with a bluish-white, flattened edge of epidermization. Raised, hard edges show disease missed in this location, and hard lumps under the skin at a distance show that regional infection was present before the operation, the latter demanding another operation followed by radiation.

The final scar after a large electrocoagulation wound is surprisingly small, soft, and made up mostly of new epidermis that has been propagated from the edges.

Secondary Hemorrhage.—One of the advantages of ionization or electrothermic destruction of a malignant growth is the sealing of the small blood vessels and lymphatics at the edge of the destroyed tissue, preventing hemorrhage at the separation of the slough, on the one hand; and, on the other, eliminating the deleterious effects of absorption of the products of decomposition—a result of heavy X-ray dosage frequently noted. That absorption of necrotic products is extremely rare or never present throughout the separation and convalescence after electrocoagulation is shown by but slight or no temperature changes following most extensive operations, this immunity being in marked contrast also to the septic conditions that so often follow extensive ordinary burns of the surface of the body. The probable explanation of the latter contrast is that an ordinary burn that permits the development of a blister fails to cause sealing of the capillary absorbents.

While the sealing of the smaller blood vessels may be equally relied upon, there are certain vessels too large for complete, permanent self-sealing in the twenty-one day maximum time for the slough to separate. These are the external carotid and its principal branches, notably the lingual and anterior maxillary arteries, which should be ligated at or before the operation. Few other vessels liable to be injured by a wisely planned electrocoagulation need this precaution, and in the rare cases (barring neck, tongue and maxillary cases), where secondary hemorrhage may appear (between the seventh and twenty-first days), it is readily arrested by a compress saturated with Monsell's Solution of the perchlorid of iron.

After Observation.—The successful outcome of apparent eradication of a cancerous growth that appears still to have been local does not end the surgeon's responsibility in the case. It is important that the patient be impressed with the need of seeking an examination by his or her physician four times a year for three years, and thereafter not less than once a year for some years longer.

OPERATIONS ON THE FACE AND SCALP

The technical details of direct current electrocoagulation of malignant growths of the face and scalp are mainly those already given for surface growths; small epitheliomata, particularly of the basal cell type, being destroyed by the unipolar method (page 195), with very fine needles (or else by electrodesiccation, page 267). For growths the size of a pea or less one need only employ novocaine or cocain by ionization as the anesthetic, the solution of the anesthetic being applied alongside the needles after insertion. The milliamperage may be suited to the patient's endurance—5 to 15 ma. or more—provided sufficient time is allowed to carry the white stain of the zinc ions entirely beyond the base of the little growth in all directions. Thorough destruction of all infected cells should not be sacrificed to fears of undue scarring, for the ultimate cosmetic results are good after destruction of facial growths by ionization. The scars are generally lineal in shape, even from irregular wounds, and smaller than anticipated.

When the epithelioma is larger than a pea, particularly if it has an indurated, reddened base or cuplike raised edges, reliance should not be placed on the unipolar method but electrocoagulation should be used. The results with the latter are quicker and more certain, and since efficient anesthesia of some kind is demanded on account of the sensitiveness of the parts, the bipolar direct current method enables us to do effective work with both the overlying growth and its basal dissemination in far less time.

Endermic anesthesia may be quite effective in the face and scalp unless the growth is large. A slight objection to it as compared with general anesthesia has been already mentioned. Unless carefully identified beforehand, the outer limit of the growth may become less easily recognized after the concentric endermic injections, which distort the edges greatly, and one is compelled at times to destroy more of the surrounding skin or scalp than would be done with general anesthesia.

The needles for face growths should correspond to the size of the growth, and when it is on the skin of the nose or eyelid should be as small, fine and sharp pointed as can readily be handled. They should be guyed in an immovable position by adhesive plaster as described on page 151, particularly when the growth is too small to support them in position after insertion.

Illustrative Cases.[1]—Case 1388. *Recurrent Carcinoma of Scalp. Three Major Electrocoagulations.* Mrs. ——, aged 67, was referred by Drs. Rimer and Clover, of Clarion, Pennsylvania, September 23, 1913. Enjoying excellent general health, a lump had appeared on the scalp behind the right ear about eighteen months before, which had been removed by excision in December, 1912, the pathologist examining the specimen pronouncing it carcinoma. Three months later recurrence was noted. On admission to the sanitarium a growth the size of a horsechestnut emerged from the scalp slightly posterior to the scar of former operation. It was firmly adherent to the underlying structures, apparently including the periosteum, and was beginning to break down. In the upper portion of the neck there was an enlarged gland, the size of a marble, situated at the posterior edge of the occipital insertion of the sterno-mastoid.

September 26, 1913. Under chloroform a bipolar electrocoagulation was done, a number of fine zinc needles being inserted beneath the growth and connected with the anode, and with the cathode applied to its center, a current of 500 milliamperes was gradually turned on. Infiltration with the ions occurred rapidly and com-

[1] Care has been exercised by the author to include in the following pages selections from only those cases whose successful treatment has been tested by time, none being cited under two years, and the majority much longer, up to twenty years since treatment. Diagnoses in all cases, except a few small epitheliomas, have been verified by a competent pathologist. For additional illustrative cases see the author's work, "Ionic Surgery in the Treatment of Cancer, etc."

plete devitalization was apparently complete in four minutes, when the current was turned off. Two minutes of maximum current of the same strength sufficed for the gland, with the needles similarly applied.

The sloughs separated duly under diluted zinc oxide ointment; but three months later, January 22, 1914, two more nodules were

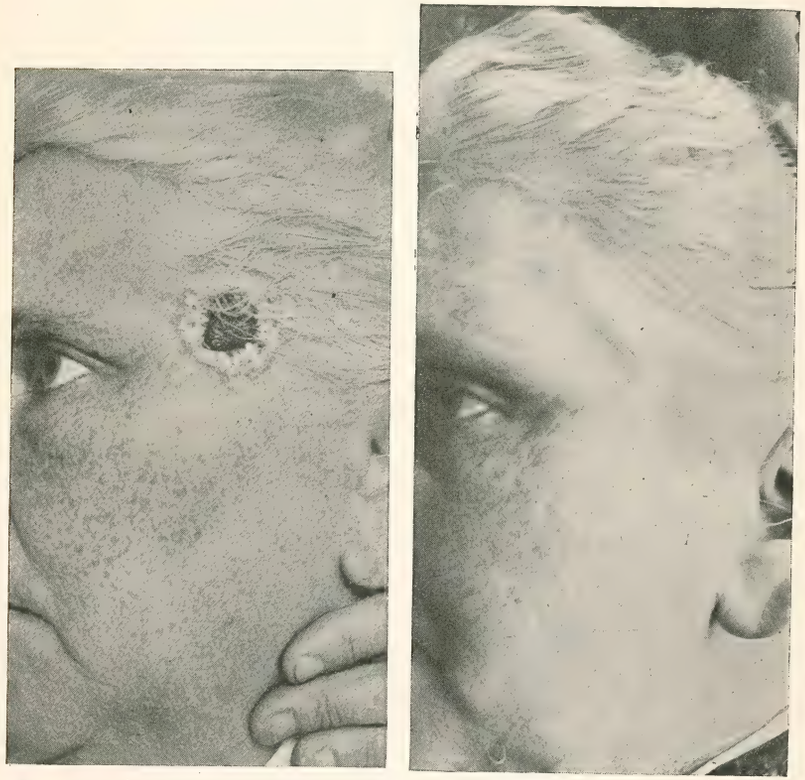


FIG. 94.—Case 1354 After Zinc Ionization on the Left, and After Healing on the Right.

found, nearly as large as the original recurrence, just beyond the edge of the scar. A second major electrocoagulation was done at this time similar to the first, except that a current of 700 to 1000 milliamperes was used for a total of seven minutes.

The high malignancy and wide spread of the cell colonies was shown in this case by a third major operation under ether being needed two weeks later, when 500 milliamperes were used for thirty

minutes. The final resulting slough revealed a small portion of the outer table of the skull denuded. The healing of the wound appeared to be assisted by phototherapy, and the patient was discharged finally from the sanitarium to the care of home physicians three weeks after the last ionization. At this time there was a sinus leading to the periosteal denudation. A scale of bone separated spontaneously later under the ointment, permitting final healing of the wound from the bottom.

There was no further recurrence of the disease, a relative reporting her in excellent health in June, 1919.

Case 1354. *Recurrent Epithelioma of Temple. Unipolar Method.* Widow, aged 62, with raised, horny growth on left temple the size of a lima bean, projecting from eroded basal-cell epithelioma (Fig. 94). Twenty-five years before a similar growth was excised from the same spot by the late D. Hayes Agnew.

August 28, 1917, unipolar zinc ionization, 35 to 48 ma. for one and a half hours, with 8 needles, under endermic injections of quinin and urea hydrochlorid.

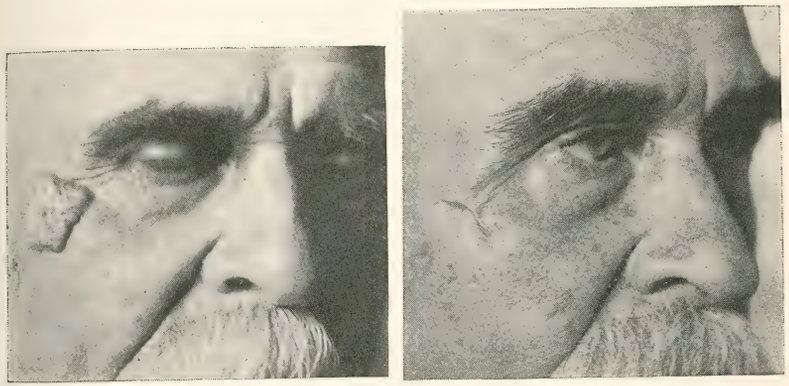


FIG. 95.—Case 1278 Before and After Treatment.

Case 1278. *Recurrent Epithelioma of Cheek. Major Electrocoagulation with Direct Current.* Retired farmer, aged 73, was referred by Dr. Helm, of Bart, Pennsylvania, August 7, 1911, with the growth shown in Fig. 95. Four years ago patient noticed a pimple at the site of the present growth, which increased in size gradually and was treated by a caustic six months ago. Recurrence since caustic treatment rapid.

There is a movable, raised, indurated growth over malar bone with scaly center and red, nodular edges.

August 9, 1911. Major electrocoagulation, 100 to 300 ma. for twenty-three minutes, under ether.

April 14, 1915. Reports free from disease, as shown in the second photograph.

Case 988. *Epithelioma of Cheek. Bipolar and Unipolar Electrocoagulation under Endermic and Phoretic Anesthesias.* Retired clergyman aged 79, referred by Dr. Park Brenneman, of Lancaster, Pa. The patient first noticed a pimple with overlying scab two years before, ulceration occurring six months later. Roentgen ray treatment had been used for a year, with some control of growth. (Fig. 96.)

July 29, 1909. Direct current electrocoagulation under endermic injection of Schleich solution, 200 to 300 ma. for thirty minutes.

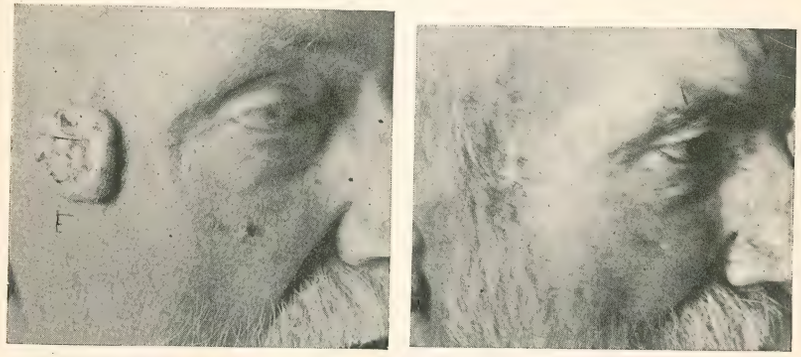


FIG. 96.—Case 988 Before and After Treatment.

The results being somewhat imperfect at some points, five unipolar ionizations were applied during the succeeding month under phoretic anesthesia with currents varying from 65 to 20 milliamperes for hour and half-hour durations. Healing was complete by October 22. The second photograph was taken about a year later.

There was no recurrence of the disease, the patient dying of old age in 1915.

Case 855. *Epithelioma of Cheek. Unipolar Ionization.* Coal dealer, aged 53, referred by Dr. B. F. Coulter, of Philadelphia. There is a raised, red tumor on the cheek near the nose (Fig. 97) that appears on palpation to be cystic. Its bright color, softness on palpation and the fact that it had existed but four months gave rise to a tentative diagnosis of sarcoma, dispelled later by Dr. Swan's opinion that it was an epithelioma.

December 7, 1908. Unipolar ionization, 15 to 20 milliamperes

for fifty minutes, four needles, under phoretic anesthesia. A specimen was removed immediately before insertion of the needles, the tumor bleeding freely. There was no evidence of a cyst.

FIG. 97.—Case 855 Before and After Treatment.

The excellent scar shown in the cut was photographed two and a half months later. Repeated examinations since have shown no recurrence.

FIG. 98.—Case 765 Before and After Treatment.

Case 765. *Epithelioma of Face. Repeated Unipolar Ionizations.* Mrs. C., aged 53, was referred by Dr. L. E. Taubel, of Philadelphia, June 4, 1908. Two and a half years before she had been struck with a toy thrown by a child and the abrasion made at the site of the present growth had never healed. Five weeks ago a rapid increase in size was noted. There is a firm, nodular growth on

the right cheek immediately below the eye, about the size of a flattened marble (Fig. 98). Pathologic report of specimen removed at first application: carcinoma.

Six unipolar ionizations were applied during the following three months, varying from 20 ma. to 3 ma. for half an hour each, under cocain phoresis. The second photograph, taken five months later, shows an excellent condition that was still present when she was last seen, eighteen months later.

Case 529. *Multiple Recurrent Epitheliomas of Face, Eyelids, Ears and Neck. Major Unipolar and Bipolar Operation.* A farmer of 45 was referred by Dr. Williams of Danville, Illinois, March 30, 1907, with the multiple epitheliomas beneath each eye, at the

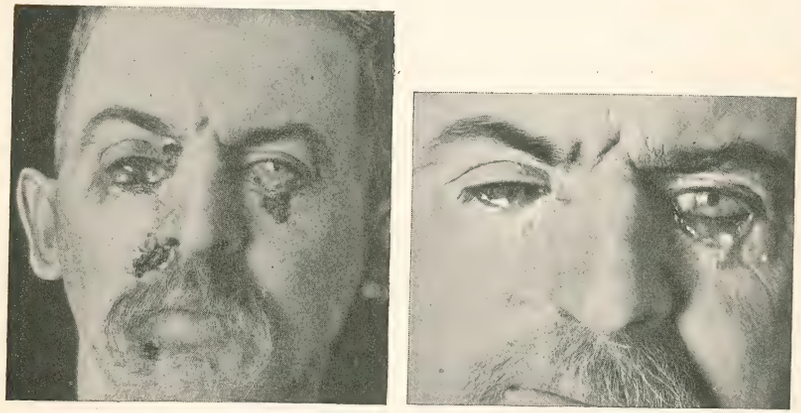


Fig. 99.—Case 529 Before and After Treatment.

side of the nose, behind each ear, and in the neck, shown in Fig. 99. The growths were first noticed twelve years before, and those beneath the eyes had been removed ten years ago, ineffectually.

The lower lids of both eyes had been destroyed, the growth also extending into the right orbit beneath the conjunctiva. But little normal tissue remained in one ear, and there were other nodes of growth about face and neck of smaller size, totaling twelve or thirteen separate centers of growth. Examination of a specimen removed at operation showed it to be squamous-celled epithelioma.

April 1, 1907. Major unipolar electrocoagulation under ether. With several electrodes in the growth beneath the right eye, the power was brought up to 250 ma., some electrodes being later transferred, one at a time, to other foci, during a total unipolar application of one hour and twenty minutes. A bipolar electrocoagulation

of 400 to 700 ma. for 26 minutes was then made to the growths back of the ears, beneath the nose, and on the neck. Several minor applications to other foci were made during the following months, and the patient returned to his home in August.

A year later he was readmitted for a small recurrence in the inner canthus of the right eye and on the face. That within the orbit was evidently imperfectly destroyed again, for he returned twice for further treatment at the canthus site during 1909 and 1910. In September, 1911, the canthus received further treatment. At this time, when the second photograph was taken, it was noted that all other loci showed healthy, hardly perceptible scars.

Case 354. *Epithelioma of Forehead. Bipolar Direct Current Electrocoagulation.* Retired clerk aged 67, admitted September, 1906. Four years ago the growth shown in Fig. 100 began, apparently as the result of a slight injury. A caustic applied two years later caused increased and more rapid growth. A specimen removed at operation

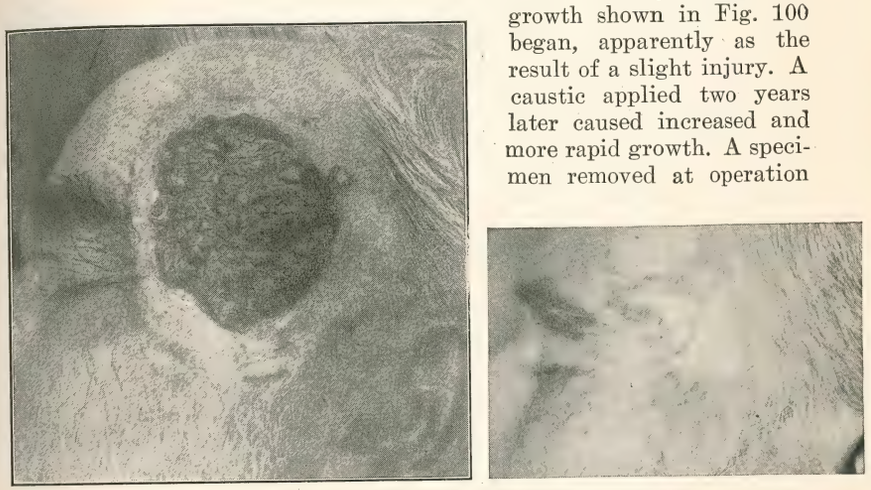


Fig. 100.—Case 354 Before and After Treatment.

was pronounced squamous-cell epithelioma by the pathologist.

September 26, 1906. Major bipolar electrocoagulation under general anesthesia of 500 to 600 milliamperes for twenty-five minutes. A pronounced boiling effect was noticed between the electrodes.

The parts healed nicely after separation of the slough. Three years later the patient reported at the hospital by request, at which time the second photograph was taken. He died of old age at the age of 76, without return of the disease.

Case 347. *Epithelioma of Cheek during Senility. Major Direct Current Electrocoagulation.* James O'D., aged 70, was admitted to hospital July 10, 1906, with the large fungating growth shown in Fig. 101. The growth began six years before, and has increased rapidly

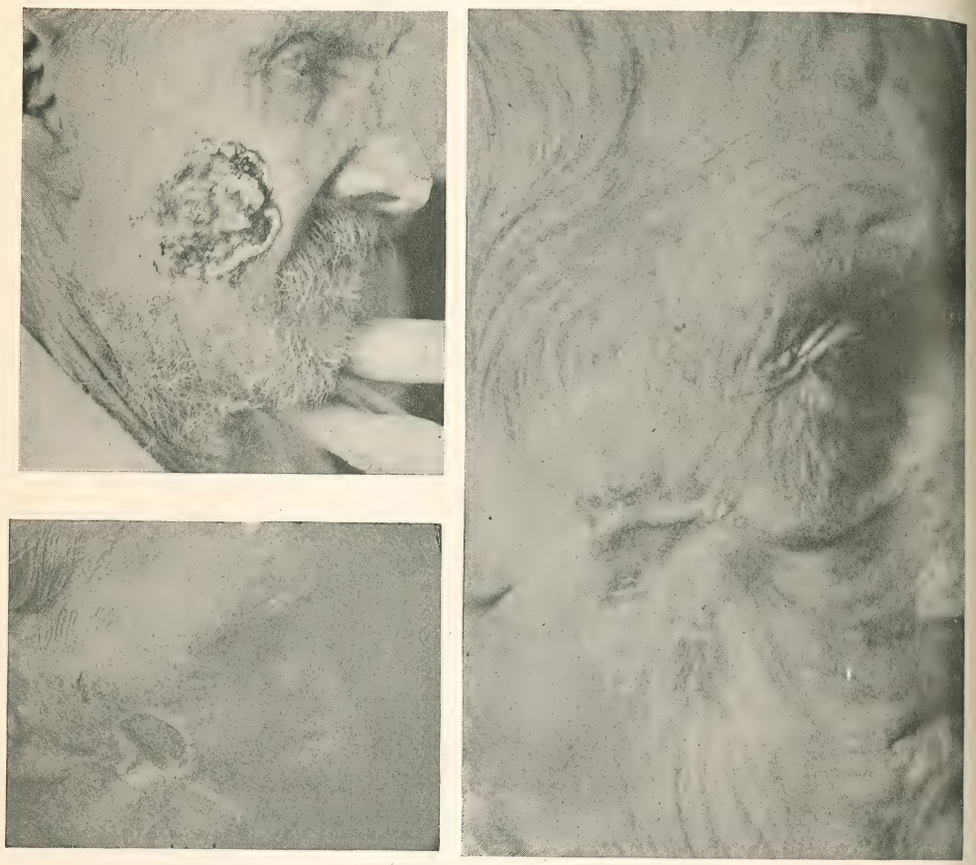


FIG. 101.—Case 347 Before and After Treatment. The bone slough is shown in the lower left photograph before its removal.

during the past year, in spite of X-ray treatment persistently applied for nine months. The patient's arteries were rigid and his general condition indicated senile degeneration, but it was decided to make an effort to relieve him. Microscopic examination showed squamous-cell epithelioma.

July 11, 1906. Major direct current electrocoagulation under general anesthesia, 500 ma. for fifty minutes. After the separation of the devitalized tissues and removal of a large bone slough from the malar bone, the parts healed over in a remarkable manner for one so feeble, as shown in the cut. There was no recurrence.

OPERATIONS ON THE EYELIDS.

The unipolar method is usually the better technic for the destruction of small epitheliomas on the eyelids or their margins. When the growth has a diameter of a centimeter or more, however, the bipolar method is more readily made effective, either with local or general anesthesia. When the lid is still retractile and the growth

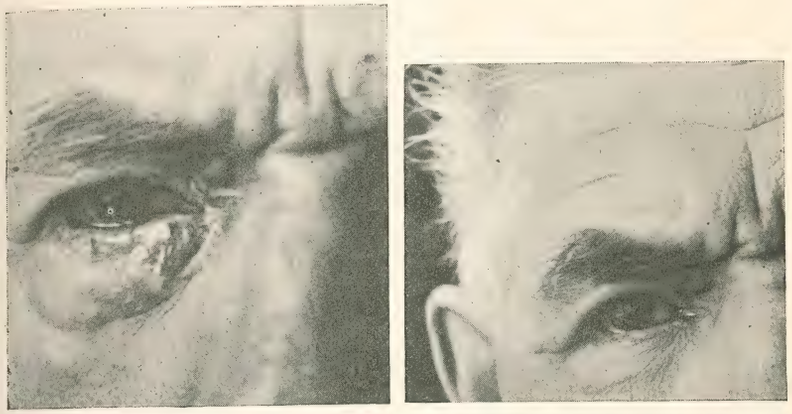


FIG. 102.—Case 1421 One Day After Treatment and After Final Healing.

small it may be held away from the eye by the fingers of the operator's left hand, lessening an unnecessary stimulus of the retina, though this has not always been possible in the author's cases, with no harmful results. A retractor may be made of hard rubber, but metal should not be used.

Illustrative Cases.—Case 1421. *Small Epithelioma of Lower Eyelid. Unipolar Ionization.* Farmer, aged 69 years, was referred by Dr. T. D. Rupert, of Geneva, New York, April 12, 1916, with a growing nodule in the inner portion of the lower eyelid the size of a coffee bean, extending downward beneath and into the texture of the skin. A unipolar ionization of 15 to 20 milliamperes was made for seventeen minutes, under novocain endermic anesthesia. The photographs (Fig. 102) show the slough the next day and the condition eight months later. There has been no recurrence.

Case 1331. *Recurrent Epithelioma of Inner Canthus of Eye. Unipolar Ionization.* Captain S., aged 50 years, master of a sailing vessel, was admitted December 8, 1911, with an epithelioma somewhat larger than a dime at the inner canthus of the right eye (Fig. 103). It was recurrent after removal at Biddeford, Maine, two years before. A unipolar application of 13 milliamperes, for twenty minutes, effectually eradicated the growth, as shown in the second photograph. Captain S. was still free from the disease when lost at sea with his vessel three years later.

Case 709. *Endothelioma of Inner Canthus of Eye. Major Unipolar Ionization.* Farmer aged 65 was admitted from Seymour, Indiana, March 12, 1908. Of negative personal and family history and

FIG. 103.—Case 1331 Before and After Treatment.

excellent general health, the present growth was noticed eleven years ago, having increased more rapidly during the past four years.

Examination shows a proliferating, ulcerating growth at the inner canthus of the right eye (Fig. 104) with three extensions: towards the bridge of the nose, and in either eyelid. The nasal extension and that in the lower eyelid were ulcerated. The conjunctiva is superficially hazy, and the upper lid could not be raised voluntarily above the pupil. Dr. Swan reported as follows of a specimen removed at operation: The tumor is composed of collections of cells around trabeculæ of connective tissue containing blood vessels. The cells vary in shape and size, the majority of them looking like large round cells, a few like spindle cells. In places the tumor shows blood spaces of varying size, some with and some without an endothelial wall. In other parts of the growth there are distinct hemorrhagic areas. Diagnosis: Endothelioma.

Operation March 12, 1908. Major unipolar ionization of 150

milliamperes for fifty minutes, under general anesthesia, with 3 to 8 fine zinc anodes. Great care was observed to limit the ionic destruction strictly to the diseased tissue. The eye was dressed with boric solution immediately after the operation.

Inspection the next day showed that the eye was in a healthy condition and the diseased parts well devitalized. On the 17th the boric acid solution was changed to a drop of atropin solution, 14 grains to an ounce, washed out ten minutes later by 10 per cent. argyrol solution twice a day. April 4 the boric acid solution compress was changed to 10 per cent. zinc oxid ointment. On April 9 the slough came away, showing an excellent condition except in the nasal side of the wound,

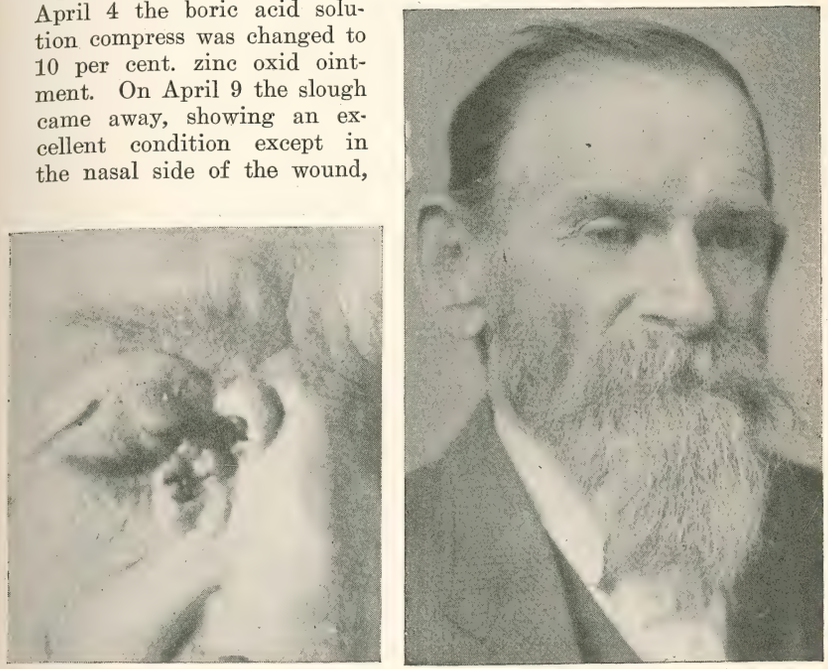


FIG. 104.—Case 709 Before and After Treatment.

where doubtful granulations received minor applications of 5 to 10 milliamperes on six occasions during the remainder of April and less current on eleven occasions during the following three months. The second photograph in the cut was sent from his home.

Case 653. *Rodent Epithelioma of Inner Canthus of Eye. Major Unipolar Ionization.* Mrs. R., aged 67, was referred by Dr. J. Gaunt Edwards, of Williamstown, New Jersey, November 23, 1907. The growth was a characteristic rodent cancer of the left canthus (Fig. 105), about the size of a copper cent, and had existed for

eight years. The eyeball was not yet involved. Microscopic report: squamous-cell epithelioma.

November 25, 1907. Major unipolar ionization under chloroform, 50 to 60 milliamperes for twenty minutes with five needles, decreasing to 20 milliamperes for an additional ten minutes.

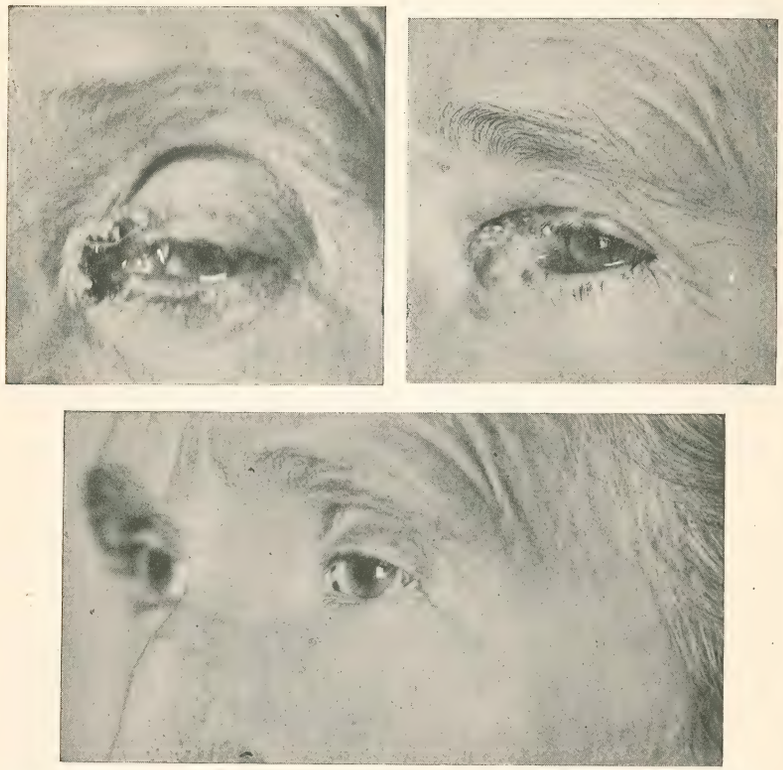


Fig. 105.—Case 653. The upper left photograph was taken before treatment; the upper right shows the result of zinc ionization five days later; and the lower photograph the final result.

The second photograph in the cut was taken five days later, and shows the slough in place; while the third photograph shows the condition two years after operation. There was no recurrence.

OPERATIONS ON THE LIPS AND NECK

Both simple zinc ionization and electrocoagulation methods are effective means for the eradication of still localized cancer

of the lips if properly applied. It is essential to their correct use that the operator fully recognizes the exquisite sensitiveness of this mucocutaneous junction, and that adequate anesthesia be used in even the smallest growth. A minor application of unipolar zinc ions that is preceded only by phoretic anesthesia will run great risk of incomplete destruction of the growth and ultimate failure to cure. Endermic anesthesia is at least demanded in the smallest growths of the lip surfaces, and permits of thorough work being done. With larger growths, general anesthesia is often more convenient for the operator; and as the time required for complete destruction by the bipolar electrocoagulation method is very brief when we are not limited in the power application by pain—often but three to ten minutes—the objections to prolonged general anesthesia are eliminated.

One of the advantages of these methods in lip cancer is that the V incision and its consequent shortening of the lip is unnecessary. A small carcinoma, projecting from the surface of the mucous membrane, needs only the thorough destruction of the indurated base and a little tissue beyond it, often not including any portion of the orbicular muscle, and resulting in but a small depression in the lip outline after complete healing. Larger growths may demand the destruction of a greater portion, or even of the whole of the lip, but in such cases the V incision would also have been impossible as a successful method of eradication.

Another advantage of electrocoagulation methods in lip carcinoma is the ease with which *movable* enlarged glands below the jaw may be destroyed at the same operation by the technic detailed below. It is true that the use of this method in the neck eliminates the removal of all the glands of the neck by dissection at the time of the lip operation, as generally advised in surgical practice. The author declined cases with glandular infection for some time for this reason, or else called in a colleague to dissect the glands out at the time of the primary operation. Unfortunately, the final results were no better and sometimes worse, with the added disadvantage of removal of some healthy glands that would otherwise have remained as buffer organs for the protection of the general lymphatic system from invasion.

The author's present practice is to accept all cases of lip cancer with movable infected glands for electrocoagulation, destroying the glands at the original operation—necessarily under general anesthesia. Cases with fixed glands, or with infected glands so deeply situated in relation to important vessels as to present

risk of serious secondary hemorrhage, are either not placed under electrocoagulation or else only after ligation of the vessels. In some cases electrocoagulation may be of use in extensive carcinomas in this region as a palliative, and to prepare the case for subsequent radiation.

Technic of Application to Lip.—If local anesthesia be decided upon, a 2 per cent. solution of novocain, or quinin and urea hydrochlorid is endermically injected on a line surrounding the growth and three quarters of an inch or an inch beyond it. The injections should begin on the commisural side rather than on the median line to block the surface nerve supply more effectually. Several minutes should elapse between the end of the injections and the insertion of the needles.

After the induction of anesthesia, whether local or general, the operation is begun by grasping the growth between the rubber-gloved forefinger and thumb of the left hand, and ascertaining by touch the exact limits of the induration, just beyond which the active needles are then inserted, side by side, a quarter to a half inch apart, the points of the needles being made to pierce the entire substance of the lip if necessary to the extent of showing slightly beyond the buccal surface, but not far enough to involve the gum in the destruction if healthy. The gloved finger is sometimes useful to act as an insulator at this point.

A cathodic electrode (Fig. 91), small enough not to touch the anodes, is then placed on the middle of the growth, being held in place by the operator, and the power is turned on by an assistant gradually until the desired effect is attained.

In a large growth that is still movable a stout thread may be passed through it by which the mass may be drawn away from the gum during the action.

Technic of Application to Movable Glands below the Mandible.—The cases in which infected glands in the neck, secondary to lip cancer, are suitable for eradication by this process are those only in which the disease is still confined to the gland structure, indicated with some probability by more or less free mobility under palpation. The best results are secured when the gland can be grasped through the skin between the thumb and forefinger and drawn slightly away from the underlying structures.

When thus protracted, it is extremely easy to insert the points of from two to four rather long active electrodes (six inches in total length to give handle leverage), through the skin back of

the gland. With a sufficient number thus inserted to cut off by destructive action all tissues back of the gland, the latter is released from the grasp and the traction continued by outward pressure of the anodes themselves, while a cathode is rested against the skin over the gland, carefully avoiding a short-circuit due to touching the active electrodes, and the power turned on to the degree of producing a boiling action in from two to three minutes.

The procedure outlined is usually superior to any attempts to cut down on the gland and pass the electrodes beneath it by sight, even when the cautery knife is used for the purpose. When the relations of the parts are thus interfered with, the operator loses a sense superior to sight—that of touch, in locating the electrodes accurately behind the gland.

Illustrative Cases.—Case 1426. *Epithelioma of Lower Lip associated with Diabetes. Bipolar Electrocoagulation under Local Anesthesia.* Commercial traveler, aged 67, referred by Dr. P. N. K. Schwenk of Philadelphia with a crusted growth on the lower lip the size of a hazel nut, with indurated base. No enlarged glands could be found in the neck. The growth had been diagnosed two years before, but the patient rejected excision.

December 18, 1916. Direct current electrocoagulation, 200 to 300 milliamperes for seven minutes, under endermic injection of quinin and urea hydrochlorid. The destruction was confined to the diseased area and its base without inclusion of muscular tissue. After healing there was no material loss of the contour of the lip. There was no recurrence.

The patient was examined quarterly for possible infected glands in the neck without any being found. His death occurred at the age of 70 from intestinal trouble.

Case 1154. *Epithelioma of Lower Lip. Major Unipolar Ionization.* Superintendent of office building, aged 60, was referred by Dr. J. M. Slaymaker, of Philadelphia, with an epithelioma on the upper surface of the lower lip near the angle of the mouth one-and-a-half by two centimeters in size, with somewhat larger indurated base. No enlarged glands were found. The growth had been recognized for six months.

November 9, 1910, unipolar ionization under ether, 50 to 100 milliamperes for sixteen minutes, with four needles.

September 12, 1911, the patient appeared with a smaller nodule at some distance from the old scar. This was destroyed by unipolar ionization under cocain anesthesia, 15 to 20 milliamperes for ten

minutes. The patient is well and free from disease at present writing, ten years later.

Case 1049. *Recurrent Epithelioma of the Lower Lip with Infected Gland. Major Direct Current Electrocoagulation followed by Minor Ionization.* Farmer, aged 72, was referred by Dr. S. Thos. Day, of Port Norris, New Jersey, with a large proliferating mass at the middle and right side of the lower lip, and a movable gland

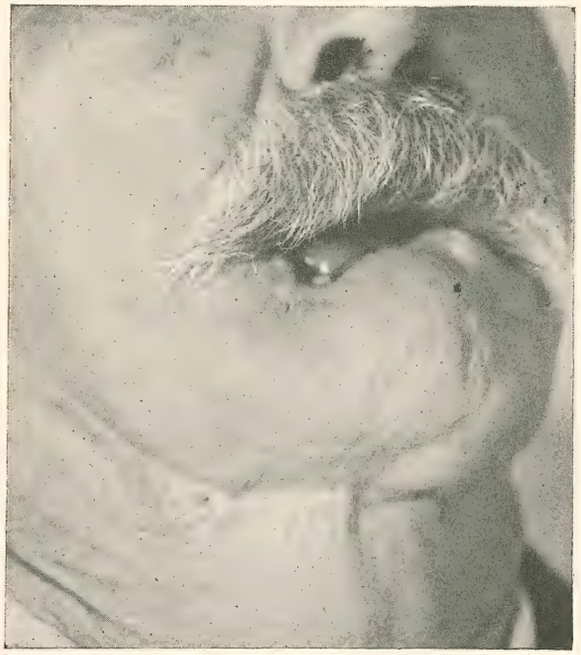


FIG. 106.—Case 1049 After Treatment.

below the mandible the size of a lima bean. The growth began thirty years before, and was recurrent after a caustic application. It had increased in size rapidly during the past six months.

January 19, 1910. Major direct current electrocoagulation under ether, 400 to 600 milliamperes to lip growth for sixteen minutes, and to gland, 100 to 300 milliamperes for thirteen minutes, the gland being held away from the underlying structures by the three long active electrodes passed beneath it through the skin.

During the healing of the wounds it was found necessary to

make three minor unipolar ionizations to doubtful spots, varying in strength from 20 to 40 milliamperes for an hour each. The photograph (Fig. 106) was taken April 6, 1911, more than a year later. A letter received in 1919 from the patient, then in his eighty-third year, states there had been no recurrence.

Case 609. *Epithelioma of Lower Lip. Major Unipolar Ionization.* U. L., farmer, aged 66, was also referred by Dr. Day of Port Norris, New Jersey, August 30, 1907. For twenty years he had had a growth on the lower lip, which had increased greatly during the

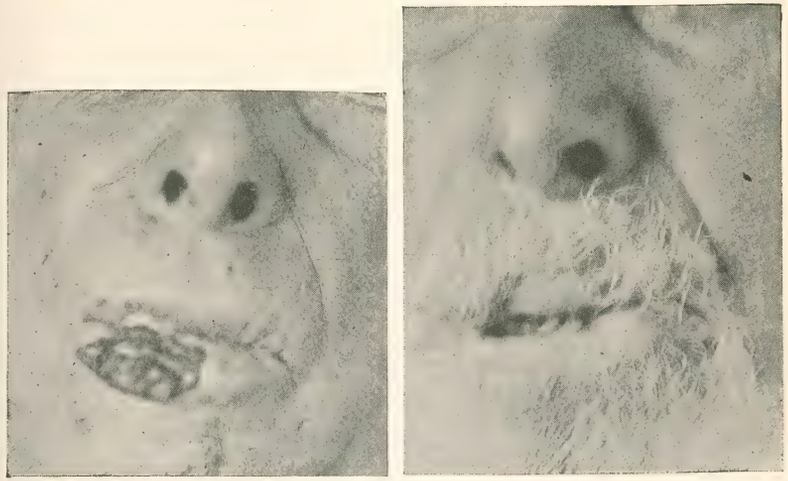


FIG. 107.—Case 609 Before and After Treatment.

last five months, during which time he had been under the X-ray treatment (Fig. 107). Microscopic examination showed squamous epithelioma.

August 30, 1907. Major unipolar operation, 300 milliamperes for thirty minutes. The second photograph was taken December, 1909, one and a half years later. A neighbor reports him free from recurrence in February, 1919.

OPERATIONS WITHIN THE NOSE AND NASAL CAVITIES.

When the growth involves the external structures of the nose the technique differs but little from that of bipolar direct current electrocoagulation of growths of other parts of the face, employing active electrodes of light weight, fine points, and only large

enough to be properly handled during their insertion into the growth; and cathodes of suitable size to make contact with the center of the growth without touching the anodes. The length of the anodes will depend on the thickness of the structure to be destroyed. The strict bipolar method permits of the use of ample power under general anesthesia with little or no diffusion to undesirable depths.

When the growth is situated within the nasal cavity the bipolar method is also the present choice of the author, even when there is but room for the two electrodes, anodic and cathodic, though an excellent success with the unipolar method is related below in case 237. With but two electrodes nevertheless, presenting but a small surface for current penetration, it is often difficult to drive enough power into a large growth on account of the drying effect and raised resistance at the site of the small anodic surface.

Preparation of Intranasal Electrodes.—An essential detail in the production of ionic or electrothermic effects within the nasal cavity is adequate insulation of the electrodes, anodic and cathodic, back of the bare points to be inserted in the growth. This is usually accomplished by fusing sealing wax (preferably of the black variety, containing no metal coloring, such as Dennison's black express wax), on the shank of the electrode, the latter being slightly heated over a Bunsen burner or alcohol lamp, passing the instrument back and forth over the flame until the coating is smooth and even, Fig. 108. Any thin spot showing in the coating may be covered by a drop of hot wax. This insulation is usually sufficient and effective, melting under action only near the point in the hottest electrothermic applications. It is a little more bulky, however, in situations where more than one electrode is inserted through the nostril than the rubber-coated instrument.

The soft rubber insulation of the latter instrument is accomplished by first smoothing all edges of the electrode and then passing over it a suitable length of fine rubber tubing in the caliber of which some talcum powder has been puffed. With suitable calibers of electrodes and tubing this results in a tight-fitting cover of little bulk, capable of being bent at any angle without injuring the insulation, and resisting heat at the end near the active surface somewhat better than sealing wax. A sufficient number of these electrodes should be prepared to supply new ones during the operation when necessary, the change

being made when the power is turned off for swabbing out the cavity and inspecting results.

The cathodic electrode may be exactly similar to the active instrument when there is but room for two electrodes passed through the nostril, but it is well to distinguish it from the anodes and insulate its conductor more effectually by carrying the soft rubber covering a yard or more over the electrode-wire junction and along the wire towards the cathodic binding post. In other words, the same rubber tubing covers the electrode and the conducting wire, thus more completely insulating this electrode from those of opposite polarity.

FIG. 108.—Intranasal Zinc Ionization Electrode. (One-half size.)

Details of Operation.—Anesthesia may be by cocain or procain in small growths, by simple osmotic diffusion and waiting the requisite time; or by general anesthesia in large growths.

A rubber sheet is laid over the chest of the patient, on which extra anodes may rest from time to time without being in contact with the patient, but the cathode when laid aside is best placed on a table near by.

With the growth illuminated by a head mirror, an anode is inserted on one side of the base of the growth and the cathode in a similar position at the other side, and sufficient power turned on. Any slight bleeding is quickly arrested by ionization and heat effects, but as the action proceeds the field of application will be obscured by a free flow of frothy serum from the cathode. This should be removed by swabbing with the power turned off, care being observed to turn it off very gradually, new electrodes inserted in better positions and the action renewed until the destruction appears to be complete. The parts will then be quite dry and retracted somewhat.

Illustrative Cases.—Case 1438. *Epitheliomatous Destruction of Nose. Major Bipolar Direct Current Electrocoagulation.* Accountant, aged 62, of English birth was referred by Dr. J. J. Frater, of Shreveport, Louisiana, for treatment October 31, 1917.

Twenty years before a scabbed induration of the right side of the patient's nose had been treated by a caustic. He came under Dr. Frater's care four years ago with the nose and a portion of the upper lip destroyed. The progress of the disease was controlled and checked for a time by the X-ray, but the condition had remained static now for some months.

Examination on admission to the sanitarium showed complete erosive disappearance of the nose save for the root, with all edges raised, indurated and

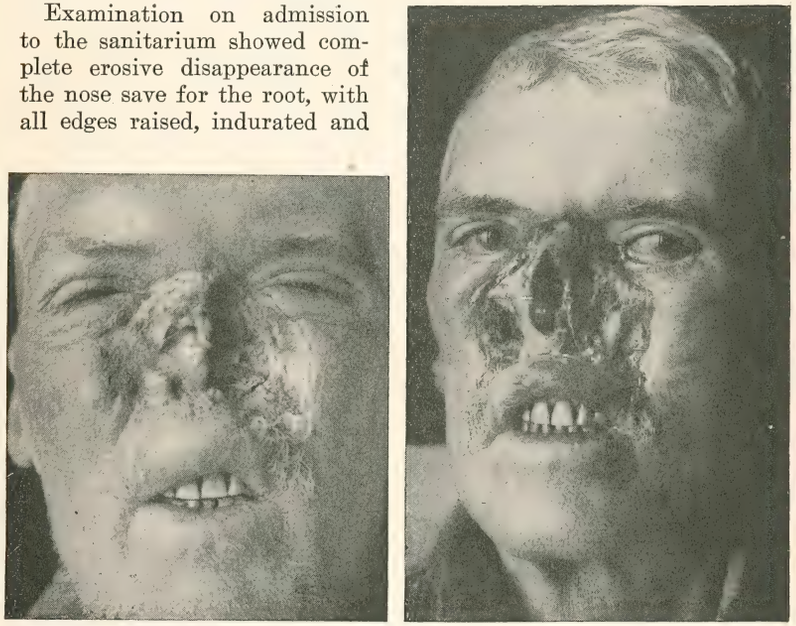


Fig. 109.—Case 1438 One Day After Electrocoagulation and Before Separation of Bone Slough.

the seat of proliferation, including the exposed edges of the septum and turbinals. The external edges of the diseased tissue extended very close to both inner edges of the lower eyelids; just within the limits of the orbital cavities; and to the middle of the upper lip, with nodules projecting into the oral cavity.

Operation, November 2, 1917, major electrocoagulation under general anesthesia. A direct current of 1,000 to 2,500 milliamperes was applied for thirty-seven minutes with twelve to twenty anodic zinc needles active at once, inserted in the edges, and a cathode resting in the center.

The operative problem thus met involved no difficulty in eradication of the disease by the newer technic of bipolar direct current coagulation, but there was the problem of preservation of the uninvolved eyeballs and of as much as possible of the lower eyelids and upper lip while doing effective work. It was evident that the direct current method with its low tension current, fine electrodes and wires capable of being handled throughout the operation presented definite advantage over other physical destructive measures.

The photograph at left (Fig. 109) taken the day after the operation, indicates clearly the limit of destruction of the lower eyelids.

Fig. 110.—Case 1438 After Healing; and with Artificial Nose Applied, Held in Place by Spectacles.

The lower half of the upper lip had also retained its vitality, though at this time it was not thought it would survive, being isolated from living tissue except at each corner of the mouth, the destructive process having been made to include the nodules protruding into the mouth.

The right hand picture in Fig. 109 shows the bone slough after separation of the soft parts. This was later lifted from the wound with little sensation to the patient, and the new bone edges became shortly well covered with mucous membrane as shown in the left hand picture in Fig. 110, these photographs being sent from the home of the patient seven months after the operation.

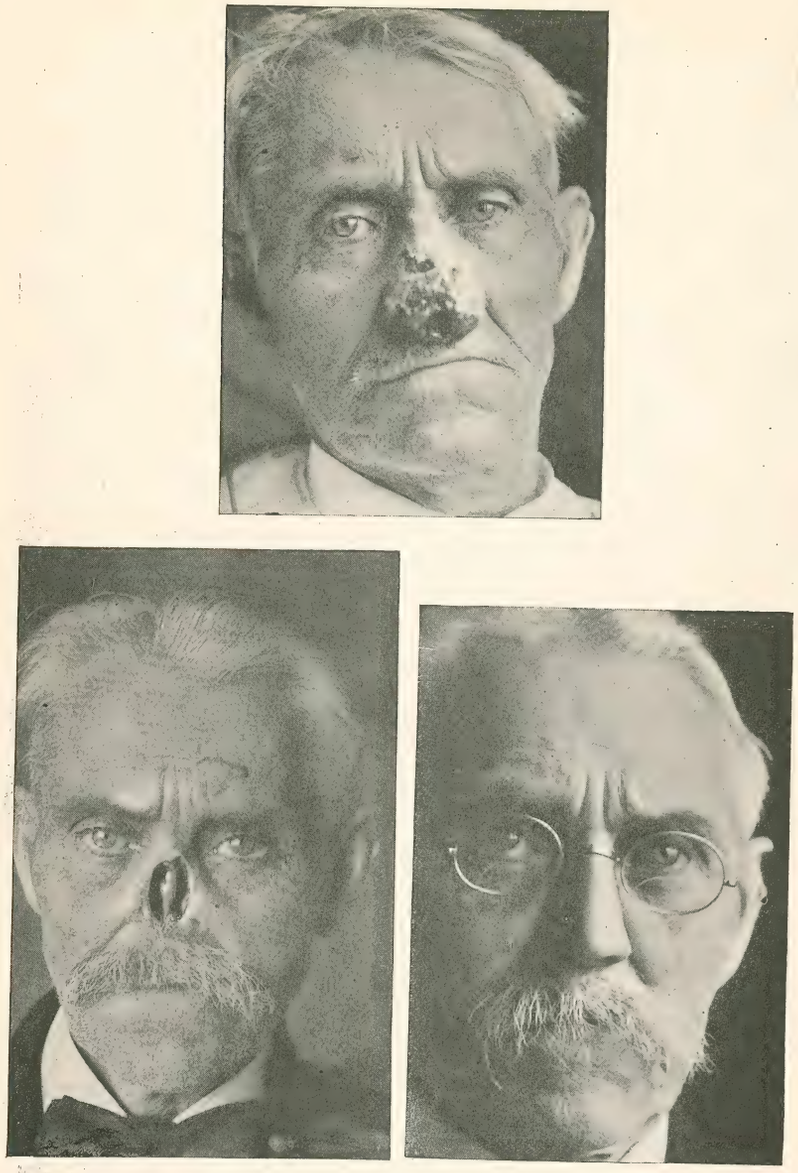


FIG. 111.—Case 1350 Before and After Treatment, and with Artificial Nose.

We were fortunate in securing the services of Mrs. Chesley, under the supervision of Major McKenzie, to do some reconstructive shielding of the defects produced by the disease.

Case 1350. *Carcinoma of Nose. Major Direct Current Electrocoagulation.* Merchant, aged 64, referred by Dr. C. L. Clover, of Knox, Pennsylvania, with the carcinomatous growth shown in Fig. 111 involving the whole external organ but not extending deeper in the nares than the external limits indicated. It had begun ten years before as a scaly spot after exposure to cold, and had been subjected to several paste applications.

July 21, 1912. Major electrocoagulation, 200 to 700 milliamperes for forty minutes.

The separation of the sloughs, soft and bony, was uneventful, and six months later the patient had an artificial nose made of dental rubber attached to his spectacles, as shown in the cut. He remains well in 1923.

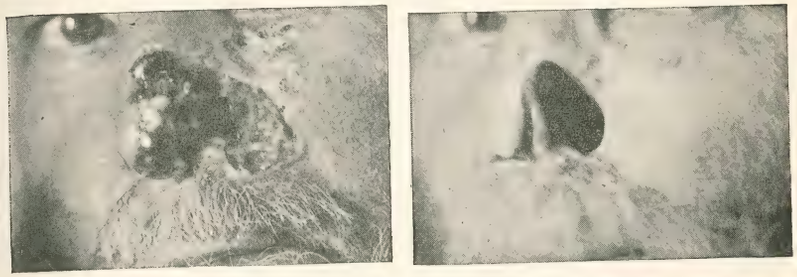


FIG. 112.—Case 998 Before and After Treatment.

Case 998. *Epithelioma of Side of Nose and Cheek. Major Unipolar Operation Followed by X-rays.* Miner, aged 69, was admitted September 3, 1909, wtih a proliferating growth on the left side of the nose and cheek that had made a large opening into the left nostril, Fig. 112. It was of two years' standing. September 6, 1909, he was placed under major unipolar ionization, 200 to 400 milliamperes being used for twenty minutes with twelve to sixteen needles. During the separation of the slough he was given some X-ray treatment as a precaution, and the bone slough (one and a quarter by a half inch in size) was lifted out November 26. The second photograph was taken June 18, 1910. Examination showed freedom from disease in December, 1911, and he reported well eleven years later.

Case 237. *Recurrent Myxofibrosarcoma of Nasal Cavity. Major Unipolar Ionization.* Mr. S., aged 41, was referred by Dr. Haas, of

Allentown, Pennsylvania, July 22, 1905. Eight months before admission the patient consulted his family physician for repeated bleeding from the left nostril. He was treated from that time (November, 1904) until March, 1905, by various methods, a growth within the nostril being finally recognized in the latter month and removed with the snare. The growth recurred and was removed again in May. In June the growth recurred a second time and was removed a third time with scissors, accompanied by alarming hemorrhage.

External examination shows a protrusion on the left side of the nose corresponding in situation with a tumor revealed within the left nasal cavity, shown by careful probing to have a broad basal attachment to the turbinal. The patient was in indifferent health, and complained of headaches.

Operation, July 25, 1905. Major unipolar ionization, under chloroform. An insulated, zinc-mercury, pointed electrode of sufficient length was inserted through the nostril into a small incision in the growth made by scissors to secure a specimen, and a current that finally attained 250 milliamperes was turned on and maintained for twenty minutes. The hemorrhage caused by securing the specimen interfered at first with the proper confinement of the effect to the diseased part, but within ten minutes all bleeding ceased, and the remainder of the application permitted of such accurate control that the comparatively strong current was confined to the proper structures and the operation was completed without injury to the nostrils.

The usual headache was somewhat aggravated the next day, but the nostril was open, owing to the retraction of the whitened necrosis. The slough came away during the second week, having been but slightly odorous under weak permanganate irrigation. Two months later the patient was readmitted for a second major ionization to a portion of the growth, on its posterior border, that had escaped the first ionization. A current of 60 milliamperes was employed for fifteen minutes. It was noted at this time that the septum had been affected by the first application, resulting in the production of a bone slough about a centimeter in diameter that came away spontaneously October 15.

There was no recurrence, the patient dying of pneumonia fourteen years later, in 1919.

OPERATIONS WITHIN THE MOUTH AND TO THE TONGUE

The situation of malignant growths within a cavity, such as the mouth, renders electrocoagulation methods of special value, for these methods enable us to reach the bases of the growths by insulated electrodes thrust into them through the natural opening, the lips being merely retracted, thus rendering disfiguring

operations on the overlying facial structures unnecessary. In favorable cases this enables us to restrict the destruction of tissue more nearly to the diseased parts alone than is possible with any other surgical method, for electrocoagulation is as easily carried out as curettement without the disadvantages of the latter procedure, chief of which is the possible reimplantation of the living diseased cells in the fresh wound.

Additional advantages of the electrocoagulation method are: its freedom from hemorrhage, especially if no specimen is removed for examination, thus making inspection of the field of operation easier, and eliminating the dangers of inspiration

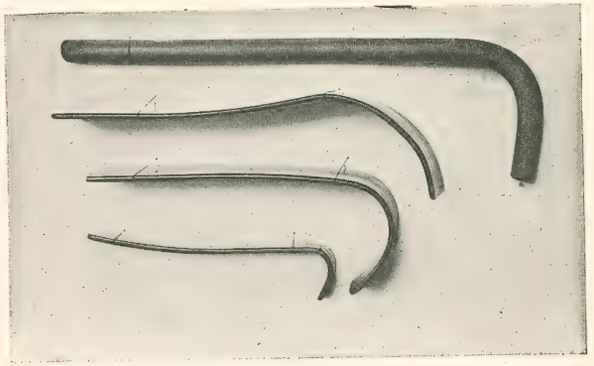


FIG. 113.—Set of Hard Rubber Retractors. (About one-third natural size.)

pneumonia. Septic conditions in the mouth are no bar to electrocoagulation, which itself is a mode of forceful sterilization.

These methods are contraindicated in serious growths near the pillars of the fauces on account of the proximity of the large blood vessels, and should be preceded by ligation of the lingual artery in all large growths of the tongue or those of any considerable size situated on the posterior portion of the dorsum. Extensive general dissemination within the mouth or the neck demands preliminary ligation of the external carotid to guard against hemorrhage at the time of separation of the slough. It is also safest at times to perform tracheotomy and retain the tube in place until healing has occurred. These procedures are not needed in many small growths of the gums, buccal surfaces, anterior dorsum of the tongue, and in the hard and soft palates.

The bipolar electrocoagulation is distinctly preferable to uni-

polar methods as the latter cause too much current to traverse vital structures in the neck, the effect on the inhibitory nerves of respiration and circulation during the unipolar application being so marked that more than 350 milliamperes can rarely be used without distinct depression, while from 1,000 to 2,000 milliamperes may be used bipolar without any such effect.

General anesthesia is necessary in all tongue operations and in all but the smaller growths of the buccal surface, chloroform being preferable, other things being equal, on account of the

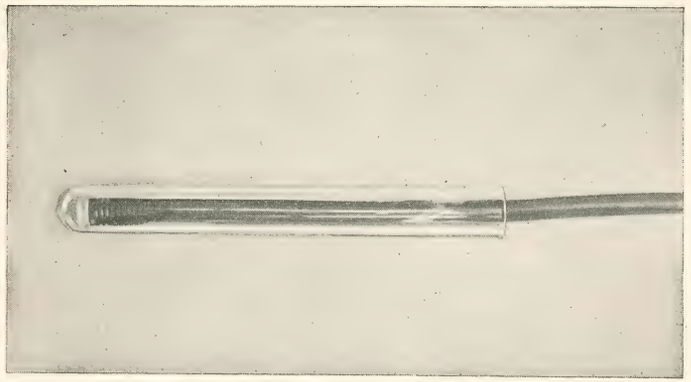


Fig. 114.—Illuminated Glass Retractor. This may be made from materials to be had at electrical supply stores; flash light bulb; a socket to fit it; lightweight double conducting cord; rubber tubing; and a test tube to cover all. A pledget of cotton wedged in the tube will hold the lamp within, and a second test tube may cover the first if greater rigidity is required. All parts that come into contact with operator or patient may be asepticized, the test tubes by boiling.

disadvantage of the free flow of saliva with ether. Preliminary hypodermic injection of atropin will lessen the latter.

A metal mouth gag may be used to separate the jaws if it is covered and insulated with soft rubber tubing, but retractors of the lips should be of hard rubber (Fig. 113). A miniature lamp may act as additional retractor as well as illuminator of the operative field by enclosing it in one or more glass test tubes, the single or double tube covers effectually insulating the lamp and its current and creating a stout retractor (Fig. 114).

During serious operations within the mouth the position of the tongue is best controlled by passing a thread through its median raphe to act as a retractor, in addition to the proper manipulation of the insulating retractors. In small growths on the dorsum of the tongue itself the author has at times dispensed with any form of retraction other than grasping the tongue in the left hand on which has been placed a sterile cotton glove, the latter permitting a firm hold to be maintained.

Electrodes.—The active anodes may be made of suitable lengths of one-thirty-second inch (1 mm.) zinc strips one-eighth inch (3 mm.) wide, and so covered with soft rubber tubing as to leave the portion to be inserted in the growth bare (Fig. 115). Their length is determined by the situation and size of the growth, varying from about four to seven inches (10 to 14 cm.). In large growths the thicker zinc electrodes, made of one-sixteenth inch (1½ mm.) plate give the needed rigidity better. These

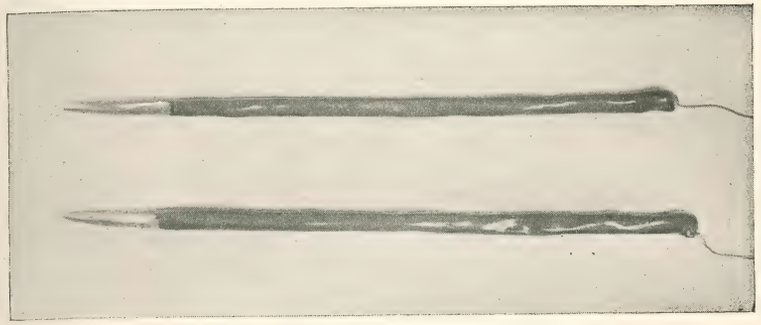


Fig. 115.—Insulated Zinc Anodes for Mouth Operations.

electrodes may be made somewhat self-retaining by notching the edges of the portion to be inserted with scissors to make several barbs, pointing backwards. They are attached to No. 30 wire conductors of suitable length in sets of six.

The cathode may be the smallest one shown in Fig. 91 with some absorbent cotton wound about its active surface and moistened, the cotton covering lessening the short-circuit should this electrode accidentally come into contact with an active electrode.

Details of Major Operation within the Mouth.—Ligation of vessels liable to cause secondary hemorrhage having been accomplished, and tracheotomy performed if needed, the rubber sheet is laid over the patient's chest, the mouth gag adjusted, the tongue and lips are protected, and one or more electrodes are

inserted beyond the periphery of the growth. The cathode is then held against its middle, and power to a strength of 200 to 1000 milliamperes or more is turned on gradually.

An abundant froth will quickly obscure the field of operation, with evidence of heat development and release of hydrogen. The temperature effect is gauged by the rubber-gloved finger, and at the end of one or two minutes, or sooner if the action seems to be extending to nondiseased contiguous parts, the power is turned off at the controller, the parts swabbed out and the extent of the action viewed by the lamp illumination. New electrodes are then inserted in advantageous situations and the procedure repeated until the parts are quite dry and inspection shows that sufficient destruction has been done. The later stages of the action may be viewed directly with the aid of the lamp-retractor, as but little moisture will then be present, but the final decision that all morbid tissue has been destroyed should be determined by the tactile sense, for carcinomatous tissue becomes soft under coagulation in spite of its drying effect.

After Care.—Beginning the day after treatment, the patient should be given a mildly antiseptic mouth wash, such as a weak solution of potassium permanganate, to keep down the increasing odor from the slough, and should have a liquid diet. The slough will come away in from seven to twenty-one days. The wound left by the slough becomes shortly painless and heals readily, usually with some contraction. Should the disease have invaded the alveolar processes of the mandible or maxilla, or the bodies of these bones, the diseased bone will be devitalized by the ions and heat and the bone slough will also separate spontaneously, the edges healing over by granulating periosteum. This separation of devitalized bone will require from thirteen to twenty-six weeks or thereabouts.

Illustrative Cases.—Case 1463. *Slowly Growing Tumor at Tip of Tongue. Major Bipolar Coagulation.* Stove assembler, age 42, was referred by Dr. Graeber, of Royersford, Pennsylvania, with the suspicious tumor near the tip of the tongue shown in Fig. 116. He had bitten the tongue at the spot six months before, shortly after which this painless lump appeared. It was growing slowly. No enlarged glands could be detected.

January 5, 1920. Major direct current electrocoagulation, 200 to 500 milliamperes for two minutes, under chloroform.

There has been no recurrence. The second photograph was taken in 1923.

Case 1457. *Epithelioma of Buccal Surface of Cheek. Major Direct Current Coagulation Operation.* Lumberman, aged 64, referred by Dr. John C. Keller of Wind Gap, Pennsylvania. Six years before admission the patient noticed a white spot on the buccal

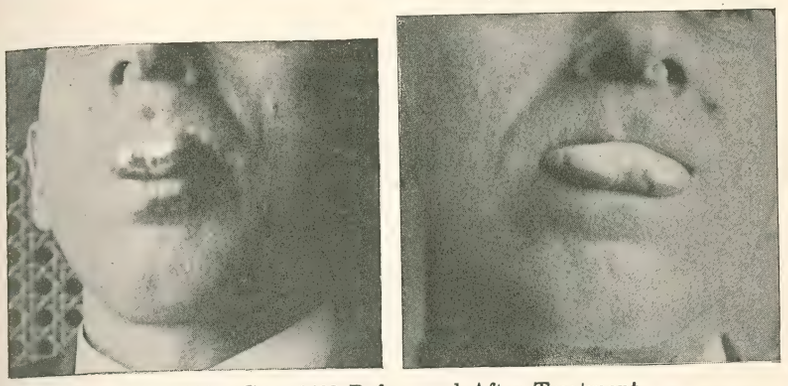


FIG. 116.—Case 1463 Before and After Treatment.

surface of the right cheek. Present examination shows an epitheliomatous growth protruding into the mouth cavity from nearly the whole of the buccal surface of the right cheek, involving the commissure of the mouth and extending through the skin at this spot. There are no enlarged glands.

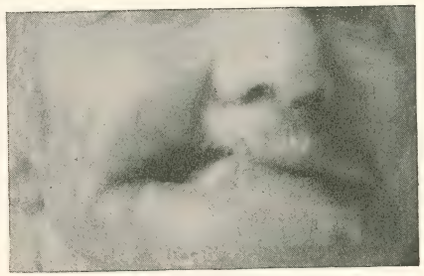


FIG. 117.—Case 1457 After Treatment. The scar tissue retracted further, nearly restoring the commissure.

October 1, 1919. Major bipolar operation, 1,000 to 2,500 milliamperes for eighteen minutes.

The separation of the slough left quite a large opening at the side of the mouth and continuous with it, and showed also a spot on the gum that had been missed at the operation. A second major bipolar operation was accordingly done November 4, 500 milliam-

peres being used for a half minute. Advantage was taken of the anesthesia to draw the edges of the wound together with sterile ligatures to lessen the opening, but the stitches failed to hold, and the parts were allowed to cicatrize at will (Fig. 117).

A letter written by the patient March 18, 1920, states that there is no recurrence; that the opening has closed satisfactorily, but that the scar tissue interferes with the proper opening of the mouth in eating.

Case 1446. *Carcinoma of Side of Tongue, Floor of Mouth and Submaxillary Salivary Gland. Major Direct Current Coagulation.* Mrs. R., aged 71, was admitted from Franklin, Pennsylvania, with a deep ulcer in the right side of the tongue and floor of the mouth the size of a horse chestnut, with a movable gland below the jaw the size of a peach stone, evidently the submaxillary salivary gland. According to statements the lump below the jaw was noticed first, four months before, and three weeks later the growth in the mouth.

June 3, 1918, major direct current coagulation operation, 800 to 1,200 milliamperes for twenty-three minutes, the application being both inside and outside the mouth, including part of the body of the mandible and all intervening tissue in the destruction. The convalescence was without incident, though her age rendered the separation of the bone slower than usual. The sinus finally healed, with no recurrence.

Case 1417. *Small Epithelioma on Under Side of Tongue. Minor Direct Current Coagulation under Local Anesthesia.* Real estate dealer, aged 72, referred by Dr. Franklin Brady, of Philadelphia. The patient had been suffering from hemorrhages from the bladder, and on the discovery of a white plaque the size of a cent, with indurated base, on the side of the tongue, Dr. Brady decided against an operation requiring general anesthesia.

January 3, 1916. The growth not being in as sensitive a part as the dorsum, the parts surrounding the growth were readily anesthetized by intramucous and submucous injections of quinin and urea hydrochlorid, and 200 to 350 milliamperes were applied bipolar for eleven minutes, the twelve needles being very fine.

The slough separated and the wound healed without incident. On May 24, the scar was found to be perfect. The patient later had another attack of vesical hemorrhage and died from uræmia June 3, 1916.

Case 1310. *Carcinoma of Tongue. Major Unipolar Ionization.* Hackman, aged 46, was sent by a committee of ladies of Newport, Rhode Island, at the instance of Dr. Wheatland, October 10, 1911. Eight months before he had bitten his tongue at the site of the

growth, the latter appearing five months later. On examination, a raised ulcerated growth with indurated base was found on the right side of the dorsum of the tongue near its base (Fig. 118), about two inches in circumference and emitting the characteristic odor. The induration did not extend deeply into the substance of the tongue, but of late had interfered with the ingestion of food. No enlarged glands could be discovered.

October 3, 1911. Major unipolar ionization, 400 to 650 milliamperes for thirty minutes, with six needles. The patient was dis-

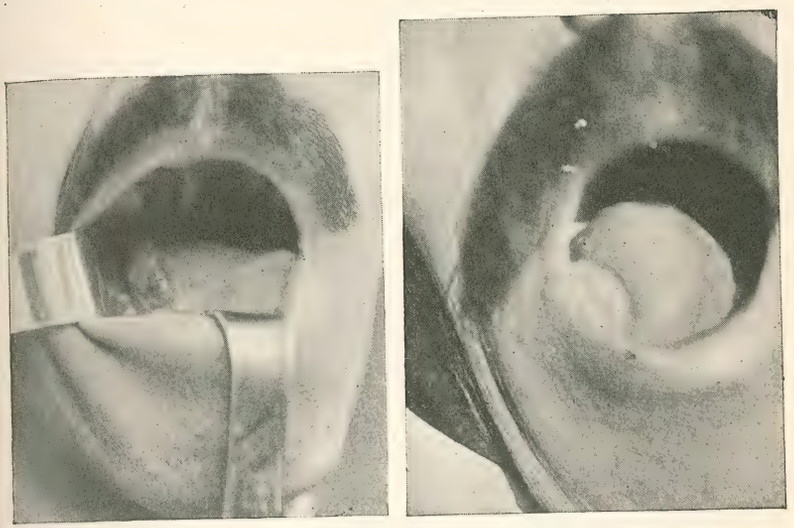


FIG. 118.—Case 1310 Before and After Treatment.

charged November 6, and returned for examination a month later, when the second photograph was taken. A recent letter from Dr. Wheatland states that there has been no recurrence.

Case 1308. *Carcinoma of the Tongue and Neck. Major Unipolar and Bipolar Operations.* Salesman, aged 56, referred by Dr. Deamer, of Philadelphia. On the right edge of the tongue, near its middle third, there is an ulcerated growth on raised, indurated base about an inch by half an inch in size. Beneath the mandible there was a movable, hard gland the size of an almond. The primary growth had first appeared but four weeks before. Specimen removed at operation was pronounced carcinoma, evidently of the rapidly growing type.

October 4, 1911, major unipolar ionization to tongue, 200 to 500

milliamperes for ten minutes, followed by bipolar coagulation, 300 to 700 milliamperes for four minutes to gland in the neck.

The patient had a severe secondary hemorrhage during the separation of the slough from the tongue, arrested by packing. On November 16 another gland at the edge of the wound in the neck that had grown large and hard was destroyed by a second bipolar electrocoagulation, with 600 milliamperes for two minutes, before some visiting surgeons in attendance on the Clinical Congress.

There was no further recurrence, the patient resuming his occupation and reporting frequently for examination. He was accidentally suffocated two years later in his home by a coin-slot gas meter.

Case 1141. *Recurrent Epithelioma of the Tongue and Floor of Mouth. Major Unipolar Ionization followed by Minor Ionizations.* Mechanical engineer, aged 44, was admitted September 20, 1910. Examination showed a proliferating growth of the right side of the tongue and floor of the mouth about one by three-quarters inch situated on a larger leukoplakial base. He had bitten his tongue at this spot three and a half years before, the epithelioma appearing in the site of the wound having been removed by excision by a Chicago surgeon twenty months before, with prompt recurrence. No enlarged glands were found.

September 21, 1910. Major unipolar ionization, 250 to 350 milliamperes for twenty-eight minutes. Several minor applications were made after the separation of the slough, and on January 20 following a spicule of devitalized bone was lifted from the wound, which healed over nicely. The patient returned to his occupation, but unfortunately met with an automobile accident February 2, 1911, resulting in his death two days later.

Case 697. *Epithelioma of Mouth with Horny Growth of Lip. Major Bipolar Operation.* E. M., aged 68, was referred by Dr. Lambert Ott, of Philadelphia, March 16, 1908. Four years before a growth had appeared on the buccal mucous membrane opposite the first molar tooth on the left side, and it had penetrated the cheek when a caustic application was made a year ago. The X-ray had also been used for a time.

On the upper lip near the angle of the mouth there are two large horns (Fig. 119), two centimeters in length by seven in breadth. Beneath these the greater part of the upper lip is thickened, indurated and covered with crusts. Within the mouth, on the buccal surface of the cheek, there is a large fungoid mass four by five centimeters broad and involving the whole thickness of the cheek. Pathologic report: squamous epithelioma.

March 18, 1909. Major direct current coagulation under chloroform, 300 to 400 milliamperes for thirteen minutes, followed by

unipolar application, 300 milliamperes for twenty-five minutes. The horns dropped off when the dressing was removed the following day and the remainder of the slough on the seventeenth day. During the next two months eight minor applications were made to doubtful granulations. The second photograph, showing a spontaneous restoration of the corner of the mouth, was taken a year and a half later.

The patient was free from recurrence in 1920, being at this time in his eighty-first year. The mouth was natural in shape, and the new tissue soft and pliant.

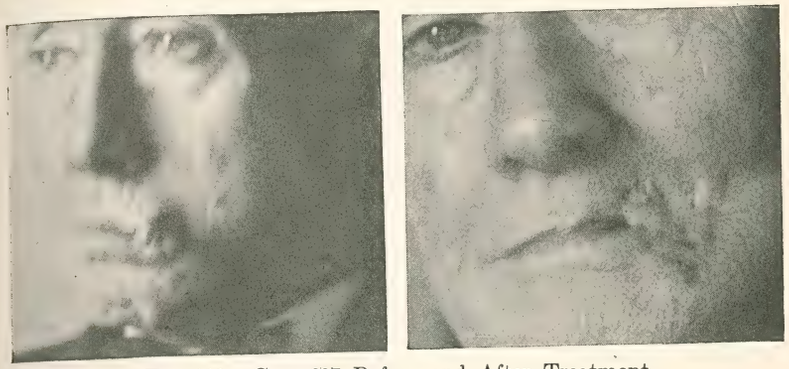


FIG. 119.—Case 697 Before and After Treatment.

Case 574. *Carcinoma of Tongue. Major Unipolar Ionization.* Mrs. T. J. L., aged 36, noticed a small lump of whitish color on the dorsum of the tongue five years ago, which increased in size gradually since, becoming ulcerated eighteen months ago. Examination June 18, 1907, showed a growth the size of an almond on the dorsum of the tongue at the left edge of its middle third. It extended deeply into the tongue to the floor of the mouth and was ulcerated on its surface. Beneath the mandible there was a movable enlarged gland that had been probably caused by a cauterization by the previous attendant, for it was smaller than it had been.

June 20, 1907. Major unipolar ionization 300 to 360 milliamperes for forty minutes to tongue and floor of mouth. (*Note.*—The operation could have been finished in a quarter of the time by the bipolar technic.) During the following two months four minor applications were made to doubtful spots. As the gland was still reducing in size nothing was done in this situation.

The patient's recovery was complete, leaving a slight tongue-tied effect on the speech. She was last seen by request December 2, 1910, at Dr. Benham Snow's office in New York, to which city she had

moved, being examined at this time by a number of physicians. The parts looked healthier and more mobile than when last seen and were entirely free from disease. The enlarged gland could not be found.

OPERATIONS ON THE BREAST AND AXILLA

Owing to the relative success of excision operations for cancer of the breast, the field for electrocoagulation in this region is more specialized than elsewhere, the chief value of the method being at the two extremes of the life history of mammary carcinoma: the earliest stage and the later stages.

The histories of some cases related below show that the very proper modern reluctance to any operation for cancerous nodules in the breast, other than complete amputation of the organ, does not hold good when the nodule is small and destroyed by electrocoagulation methods, together with only such contiguous tissue as to make sure of all possibly infected environment. The reason, of course, is that by this method all infected tissue, *if actually included in the chemic and thermic devitalization* is killed *in situ,* with no possibility of operative reinfection. Successful results of this kind demand a delicate diagnostic sense that will select only cases in which adequate results may be accomplished, a diagnostic sense mostly tactile, together with the control of the movements of the patient for several years after, so that any palpable gland in the axilla may be destroyed by bipolar action as soon as found. When there is doubt on either point, the proper course is complete destruction of the breast and axillary contents by direct current electrocoagulation, a result that may be accomplished in about one quarter of the time under anesthesia demanded by the modern excision or amputation.

We may not see many early carcinomas of the breast in the stage in which most of the breast may be saved by this free destruction of the diseased area alone, but if the education of the public is advanced in this matter we may see more. An instilled hope that the breast may be preserved in young women, while the cure is immediate and radical, may result in earlier diagnoses than are unfortunately prevalent at present.

The second class of cases in which electrocoagulation methods are indicated includes those near the stage of inoperability by the knife, where massive chemical heat may ensure sterility of operative edges, without loss of blood at the operation or afterwards (for secondary hemorrhage after breast and axillary coagulations are extremely rare), and no loss of blood whatever need occur during the operation save that cooked within the diseased tissue.

The destruction of all axillary contents, in particular, is readily accomplished by these methods, without material interference with the pectoral muscles, *which are always preserved after these operations if not already eroded by the disease.* When partly invaded by the disease that part alone need be destroyed. The ease with which the electrodes may be passed between the ribs and the disease up to the apex of the axilla, and all tissues thoroughly cooked in a few moments between them and a cathode placed on the skin is a most interesting demonstration. It has been urged by surgeons who have not seen the axillary contents destroyed in this manner that such destruction of infected glands at the apex of the axilla would endanger the blood vessels. The author has had no serious hemorrhage in this situation, though slight venous oozing has been temporarily present in two cases. It should be guarded against by keeping the points of the electrodes a little short of the apex. When the slough comes away, a most perfect revelation of the axillary cavity is presented to the eye, and if a gland or glands have been missed at the apex, they can then be seen lying loose in the cavity like a small bunch of grapes. It is then an easy matter to destroy them at once by a few milliamperes applied unipolar from several fine needles, without anesthesia of any kind being needed, for the parts are practically free from sensory nerves, the destructive effect being gauged accurately by the eye. This secondary application is usually done, when needed, in the second or third week.

Whenever a palpable gland is detected in the axilla the axillary contents should be destroyed *en masse,* together with the entire breast at the original operation. This should be accepted as the rule.

All surgical methods, including those under consideration, will of course fail to reach infected glands higher than the apex of the axilla; and when the supraclavicular glands are also infected these methods are of little or no value.

Details of Direct Current Coagulation of Nodules in Breast.—General anesthesia is to be preferred, particularly for growths near the nipple, unless there is a contraindication, when thorough endermic local anesthesia may be made fully effective.

Whether general or local anesthesia be used, small nodules are best destroyed without any attempt at specimen taking, for if the overlying skin be undisturbed the nodule may be easily grasped in the fingers of the left hand, and so drawn away from the under parts as to render insertion of the electrodes beneath the nodule more effective in the inclusion of all disease in the action than possible otherwise. The author makes this statement after a long course of specimen taking in the interest of scientific accuracy, in which the true interest of the patient was not advanced at times by this observance of convention, for all landmarks are lost when we incise the tissues over the tumor. The observance of several cases of recurrent carcinoma of the breast in scars made by competent surgeons for the removal of what was pronounced by them benign tumors has lessened my reliance on the value of a negative report.

The active electrodes and the indifferent cathode are those described elsewhere (Figs. 90 and 91, page 197) as employed in minor direct current coagulation, this being the preferable technic in these cases. The small slough may be removed by scissors after the completion of the minor operation or left for spontaneous separation as preferred. In all cases the parts are dressed with the dilute zinc oxid ointment (page 207), with abundant overlying absorbent cotton until the wound heals by granulation and epidermization.

Details of Major Direct Current Electrocoagulation Operation on Breast and Axilla.—*Assistants.*—In addition to the anesthetizer, three assistants are required: one to handle the cathode, one to turn the power on and off at the controller, and one to note the pulse and make records, the number being reducible to two if the two last mentioned functions be combined.

Active Anodes.—With the patient prepared and anesthetized as described at page 204 four sets of active electrodes (uncoated zinc anodes about seven inches in length, as shown at C in Fig. 90) are laid in order on a glass table top near the operating table in sets of six, permitting the use of twenty-four if needed, ready for their joint wire ends to be caught in the clips of the multiple connector as required.

Multiple Hook Cathode.—Long experience has convinced the author that a large mammary tumor or any other large tumor of the surface is best drawn out from the chest wall during the whole of the operation. This permits of a better insertion of the electrodes back of the tumor and just beyond the diseased

tissue, and lessens the chance of a spread of the heat and ionization closer to the ribs than is desired. This is best accomplished by a set of six steel hooks (Fig. 120) insulated by soft rubber tubing passed over connecting wire and hook in one piece, covering the whole except the part of the hook to be inserted in the tumor. These hooks are seven inches long with an inch and a half curve and an eyelet in the distal end. To this eyelet the

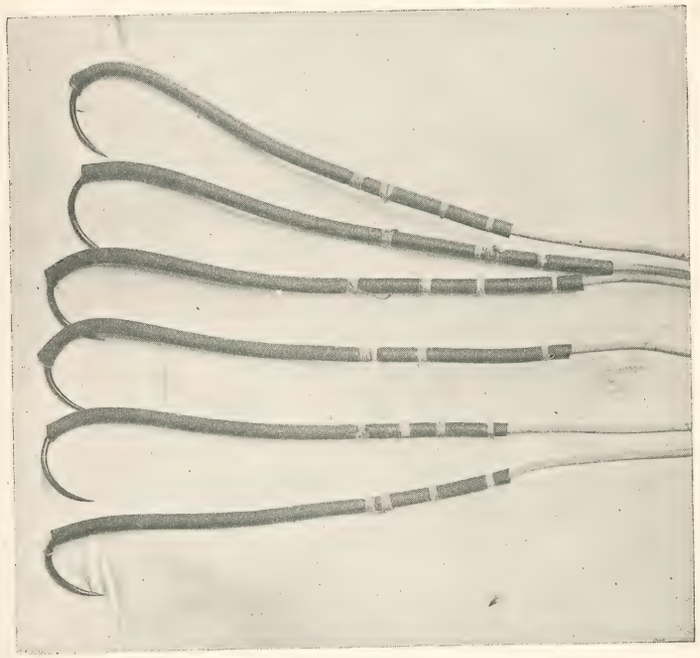


Fig. 120.—Multiple Hook Cathode. (About one-fourth size.)

bared end of a piece of strong copper cable, seven feet long, is attached by threading and winding, and over the wire and electrode three feet of small caliber rubber tubing is passed, covering the shank of the hook to its bend and extending down the wire about two feet. Over the wires of the six hooks thus prepared a five foot piece of rubber tubing is then slipped, this tubing being of sufficient caliber to cover about two inches of the distal ends of the smaller tubing, thus making a multiple instrument well protected from short-circuiting by touching the anodes and their

slightly insulated wires except at the contact surfaces of the hooks themselves. Either one or more of these hooks may be used as the cathode in large growths, the separate wires being long enough to permit the remainder not then in use to be placed on a near-by table. The flat cathode, Fig. 91, is also attached and laid aside on the table.

Details of Operation.—With the anesthesia complete, a rubber sheet is laid over the patient below the field of operation and one hook is inserted in the tumor about an inch inside its upper edge, with the point of the hook directed towards the center of the growth. One or two other hooks are similarly placed an inch apart, permitting the growth to be drawn away from the chest by the left hand of the operator or by an assistant. The first anode is then inserted beyond the upper edge of the growth, parallel with the border of the pectoral muscle but not in it if it is not manifestly diseased, and with its point carried well up into the axilla by touch. It is generally necessary to incise the skin with the point of a small bistoury for the insertion of these large anodes as resistance given by a tough skin lessens the delicacy of the proper placement of the electrode.

As soon as one anode has been properly inserted the current is turned on gradually and steadily by the assistant at the controller, while the operator inserts additional anodes, and also an additional cathode as needed, in the progressive devitalization of the base of the growth.

The plan of operation is to devitalize a broad sector of the growth and nearest tissue between anodes and cathodes, the action being carried around the pectoral edge, the lower edge, and finally the axillary edge, concentrating the current on one or more sections at a time to render the action most effective, each devitalized section extending nearly to the center of the growth. To insert all the electrodes before turning the current on would demand more current than usually available. As one section thus treated turns white and steams sufficiently to ensure devitalization, new electrodes are inserted in fresh tissue to divert the current before the first ones are removed and laid aside on the table, well out of the possibility of contact with a cathode. In this progress around the edge and bottom of the growth, previously used electrodes may be employed in a new situation, but they have the disadvantage of being somewhat roughened by the ionization. The cathodes should also be changed in position from time to time to make the action more direct in a

given section, all of the six hooks being used whenever there is room for them. The result is a combined ionization and electrocoagulation up to the boiling point of the whole base of the tumor, without special attention to the central mass, which by this time has been honeycombed and softened by cathodic electrolysis and heat.

As the operation approaches completion in the mammary mass, all of the anodes first inserted are removed, the circuit being maintained by those more recently inserted in the axillary side. Anodes are now passed beneath the axillary contents, converging near its apex, the exact position of the points being determined by touch through the skin. The cathodic hooks are now removed except enough to maintain the circuit, and a flat cathode (Fig. 91) is laid on the skin surface of the axilla and, with a sufficient number of anodes beneath the axillary contents, electrocoagulation is accomplished in a few moments, as manifested by a whitening color and boiling temperature.

With all possibly infected tissue thus devitalized, the power is turned off, the final electrodes removed and the greater part of the dead mass clipped away with scissors. This will reveal whether any portion of the base of the growth has been missed. If so, one or two electrodes should be reinserted beneath the doubtful spots, a cathode placed above them and sufficient power turned on to destroy these parts also.

This operation demands special care when the left breast is the point of attack on account of the nearness of the heart. Full traction should be used with the hooks at this point and a minimum current for the purpose, which may be further concentrated to needed spots by severing the dead tissue with scissors as soon as it is devitalized.

After Care in Breast Cases.—Since these operations may be completed in thirty to forty minutes, without loss of blood, patients recover quickly, though there may be sufficient pain to render a hypodermic dose of morphia helpful.

The wound is dressed with plain gauze after the operation. At the dressings thereafter warm ointment (page 207) is poured over the wound, covered with absorbent cotton and a six-tailed binder. A line of demarcation will gradually form, separating the remaining crust from the underlying tissues. The slough thus formed will separate spontaneously between the fourteenth and twenty-first days after operation or thereabouts, leaving a clean wound. This wound is painless as a rule, and should be

dressed daily in the manner described above, an abundance of the warm ointment being poured over the wound before applying the absorbent cotton, the ointment being in sufficient quantity to prevent actual contact of the cotton with the granulations. When the dressings are removed the granulating surface will be found to be clean, and it should not be washed or disturbed in any way, only the surrounding skin being cleansed with soap and water, with an occasional removal of the ointment adhering to the skin by pledgets of cotton dipped in gasoline.

During the healing of the wound it should be critically inspected, particularly the axillary apex, for undestroyed remnants of the disease, shown in a possible undestroyed gland or raised, hard granulations, and a minor unipolar application should be made with a sufficient current and needles to secure effective results as soon as a decision as to their nature is made. As there are no sensory nerves in exposed glands or granulations at some distance from the skin edge no anesthesia will be required, even for a current of 50 to 100 milliamperes for an hour.

Postoperation X-rays should not be used at this time in wounds that appear to be healthy, or in which a few minor ionizations or desiccations may secure a radical success, as radiation will so alter the surface of the wound as to conceal any possible remnants until it is too late for further prosecution of the method.

Large wounds produced in the destruction of breast cancer are ultimately covered in large part by epidermic propagation from the skin edges when dressed by the ointment as described, and in part by retractile scar tissue, the final scar occupying but a small area compared with the original wound.

Patients should be directed to seek examination by their physicians four times a year for three years from their discharge, and thereafter once a year.

Illustrative Cases.—Case 1474. *Carcinoma of Right Breast. Major Direct Current Coagulation of Breast and Axillary Contests.*

Miss M., aged 49, was referred by Dr. A. Rieger, of New York, August 15, 1921, with a large carcinoma of the right breast, of two and a half years' duration. The whole of the right mamma is involved, with adhesion and erosion of the skin in the lower quadrant. Circumference 13 inches by 8 inches. No glands palpable in axilla or above clavicle.

Under ether, the whole mass was retracted with the tenaculum cathodes, anodes were inserted beneath, reaching into axilla, in sections of six anodes at a time, and 3,000 to 4,000 milliamperes of

direct current employed for forty-five minutes. During this time the anodes were transferred to new segments as the tissue was destroyed, and the tenaculæ replaced by the surface cathode for treatment of the axilla. The recovery was uneventful, and the patient was seen in June, 1923, with excellent scar, complete use of arm (including ability to arrange her back hair), and improved general health.

Case 1469. *Recurrent Sarcoma of Male Breast, with Pronounced Valvular Heart Disease. Direct Current Coagulation, followed by High Frequency Coagulation* under Local Anesthesia.

Builder, aged 43, was referred by Dr. Joseph B. Shaw, of Trenton, New Jersey, with the recurrent tumor of the right breast shown in Fig. 121.

FIG. 121.—Case 1469 Before and After Treatment.

Seven years before Dr. Shaw had removed a tumor thought to be benign from the site of the present growth. Recurrence became visible about four and a half years ago, and the growth is now larger than when first removed. No pain, tenderness or ulceration are present, and the patient is in good health save for pronounced valvular heart disease, with poor compensation.

February 17, 1921, about three-fourths of the growth was destroyed by bipolar direct current coagulation, under local anesthesia, a current of 1,600 to 2,500 milliamperes being maintained for two hours and thirty minutes. As the patient was by this time quite exhausted, though suffering but little pain, the destruction of the remainder of the growth was postponed.

One month later the remaining portion of the growth was destroyed by coagulation with the d'Arsonval current, about 1,200 milliamperes being the limit of bearable pain. There has been no recurrence.

Case 1428. *Early Carcinoma of Breast and Axilla. Major Direct Current Coagulation.* Widow, aged 36, whose husband had died of cancer of the stomach six months before, discovered a lump in the left breast three weeks before admission. On examination, a painless, movable tumor was found in the upper, inner quadrant of the left breast, with an enlarged gland the size of a small lima bean in the left axilla.

FIG. 122.—Case 1428 After Treatment.

March 12, 1917. Major electrocoagulation, 1,000 milliamperes for ten minutes to breast and an additional two minutes to the gland in the axilla.

September 17, 1919. Patient examined and photograph taken (Fig. 122). The scar is in excellent condition and free from recurrence, and the patient has gained weight.

Case 1427. *Carcinoma of Right Breast. Major Direct Current Coagulation.* Married woman, aged 36, had noticed a hard spot in the right breast before the birth of her last child, now seven months old, and had been unable to use this breast in nursing the baby. The growth had recently shown an increase in size and given rise

to "sticking" pains. Examination showed a greatly retracted right nipple, and on palpation an irregular, nodular flat mass beneath the areola. No enlarged glands were found.

December 31, 1916. Major electrocoagulation, 1,000 to 2,000 milliamperes for thirty minutes to breast and axilla—the latter as a precaution.

An excellent scar resulted, and the patient remained in good health until her death from influenza during the prevailing epidemic in 1918.

FIG. 123.—Final Scar in Case 1347.

Case 1407. *Carcinomatous Nodule in Male Breast. Major Direct Current Coagulation.* Bookkeeper, aged 62, in fair general health, discovered a lump in the right breast several weeks before admission. The lump was painless. Examination showed a hard tumor the size of a horse-chestnut beneath the areola of the right breast. There was no evidence of enlarged glands.

April 14, 1915. Major electrocoagulation, 500 to 700 milliamperes for nine minutes.

The patient was in excellent health, with a small linear scar when seen in 1920.

Case 1347. *Tubular Cancer Beneath Nipple in Aged Woman. Minor Bipolar Ionization.* Widow, aged 74, seen with Dr. Van Gasken, of Philadelphia, had noticed evidences of Paget's disease of the nipple eighteen months ago. Examination showed redness of the left nipple and areola, beneath which there was a movable lump

nearly as large as a golf ball. The breast was soft and pendulous and otherwise normal for a woman of her age, and no enlarged glands were found. General anesthesia was thought to be unnecessary and unwise in view of the patient's age.

June 14, 1912. After circling the diseased area with endermic injections of quinin and urea hydrochlorid at a distance of a little more than an inch from the growth, followed by deeper injections beneath it, the growth was encircled by small anodes that met beneath it and with a cathode held against the surface a current that was at first quite gentle was turned on. The power was gradually increased with but little suffering on the part of the patient until 1,000 milliamperes was reached. The total time consumed was fifty minutes.

The result was excellent, as shown by the photograph, Fig. 123, taken some eighteen months later. There was no recurrence up to the time of the patient's death from old age, some four years later.

Case 1343. *Carcinoma of Left Breast. Major Direct Current Coagulation.* Mrs. S., aged 42, referred by Dr. Marks, of Reading, Pennsylvania. Fifteen months before admission the patient noticed a lump the size of a marble in the upper, outer quadrant of the left breast. Examination at admission revealed a large carcinoma involving the whole of the mammary structure with a cauliflower-like protrusion through the skin near the nipple. She had fallen off in weight from her usual 152 pounds to 135 at present. No enlarged glands could be detected.

March 19, 1912. Major bipolar electrocoagulation, 2,500 milliamperes for one hour, to entire breast and axillary contents. The convalescence was uninterrupted.

A letter from her husband dated April 2, 1920, states that the patient continues well, doing all of her household work except washing and ironing.

Case 257. *Carcinomatous Nodule in Breast, Followed by Axillary Involvement. Two Electrocoagulations a Year Apart.* Miss T., aged 25, had first noticed a small tumor in the left breast two or three years before admission. It was not tender or painful, but had lately increased in size. Examination showed a movable tumor the size of a peach stone, with ill defined edges. No axillary or supraclavicular glands were palpably enlarged and the general health was good.

October 31, 1905. The clinical indications pointing to carcinoma of the breast in its early stage, subsequently verified by examination of a specimen removed at the operation, it was decided to save the breast by destruction of the tumor *in situ*. She was accordingly placed under general anesthesia on this date, a specimen removed

for histologic examination, and a bipolar application of 200 to 350 milliamperes made for fifty minutes.

September 25, 1906. An enlarged gland is now palpable in the left axilla, movable, and the size of a small bean. The scar of the

Fig. 124.—Final Scars in Case 257. At left the scar in the upper part of the breast is seen and at right that in the axilla.

primary growth is excellent. It was decided to destroy all axillary tissues together with the gland, as a precautionary measure; this was done on this date by a unipolar application of 300 to 400 milliamperes for thirty minutes. (*Note.*—The bipolar method would have been more conveniently used.)

The photograph, Fig. 124, was taken four years after the first operation. The patient's condition in June, 1923, is excellent, nearly seventeen years after the second operation.

OPERATIONS ON THE NECK OF THE UTERUS

Electrocoagulation is an ideal method of eradicating an incipient carcinoma of the uterine cervix. It is quickly applied; may be pushed without general anesthesia up to 400 milliamperes, and to 1,000 milliamperes under ether; and can do no harm in skilled hands.

But, unfortunately, the practical use of the method has met with as little final success in the eradication of carcinoma of the cervix as have the older methods, for the reason that incipient cases are conspicuous by their rarity in the practice of all gynecologists. Until a campaign of education that will cause women to seek preventive examinations at half-yearly intervals is successful, and that will arouse their first medical attendants to the importance of immediate destruction of suspiciously hard spots about the os, with or without ulceration, we will make no progress, and the rôle of electrocoagulation will be that of a valuable palliative, or an admirable preparative agency for radium therapy.

The reason for this pessimism, applicable to any purely local method of attempted eradication of cancer in this situation, is that most forms of carcinoma of the cervix share with mammary carcinoma the tendency to early dissemination into near-by structures and early infection of regional lymph glands, while the chances of early discovery are far less; and, unlike mammary carcinoma, the situation of cancer of the uterine cervix does not permit of equally extensive and effective destruction of near-by tissue.

Technic of Electrocoagulation of Carcinoma of the Cervix Uteri. *Instruments Required.*—The diseased area may be exposed in either the dorsal or the Sims position. Cylindrical glass specula are used in the dorsal position, of a length and caliber appropriate to the particular case, while in the Sims position the cervix is exposed by a Sims' speculum which has been temporarily coated with fused sealing wax as insulation or by a similarly shaped hard rubber retractor. For retracting the anterior wall of the vagina a hard rubber retractor must also be provided.

Illumination is obtained by a miniature lamp encased in a slender glass tube, similar to that employed in rectal operations (Fig. 149, page 336), though the vaginal instrument must be of less caliber and the shank longer.

Anodes.—The Anodes are slender zinc electrodes (Fig. 125) made from $\frac{1}{32}$ inch zinc plate covered with thin rubber tubing to one centimeter of their tips, which are sharpened, and at times barbed at the edges to be more self-retaining. About three,

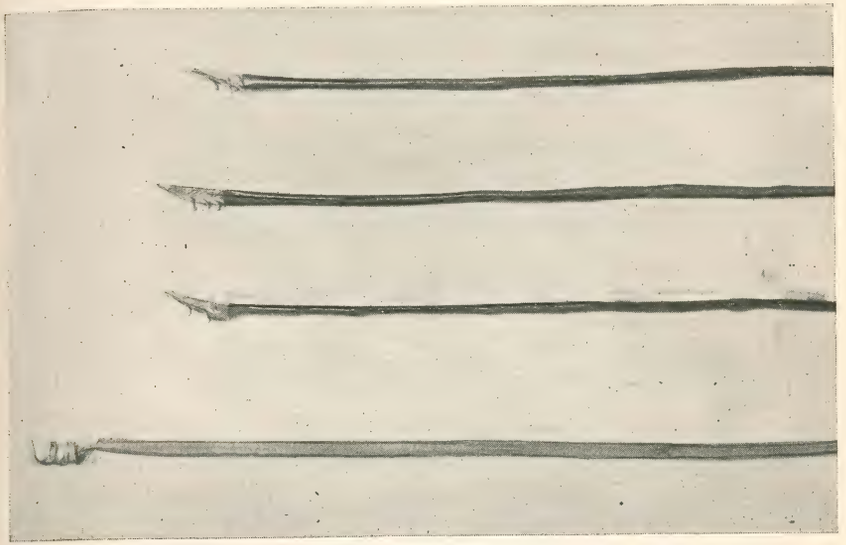


Fig. 125.—Above, Anodes for Direct Current Coagulation of Cancer of the Cervix. Below, Corkscrew Cathode for same (about one-half size).

as many as can be used through the cylindrical speculum, are employed.

The Cathode.—This instrument is made of the same material as the anodes with the same covering of rubber tubing (the tubing being prolonged down the wire a yard or more to distinguish the cathode and insulate its wire from the anodes), but more metal is left bare at the tip and the tip is curled into a small spiral with a sharp point, resembling a small corkscrew. This spiral is readily formed on the tip of the instrument by bending it around a cylinder such as a lead pencil, or a smaller cylinder if the growth be small. (Fig. 125.) This corkscrew

tip permits of the instrument being screwed into place in the center of the growth, lessening the risk to the apparatus of short-circuits under the liquefying action of the power.

The Operation. Sims' Position.—With the patient in the correct Sims' position, lying on the left side with the left arm drawn back and the right knee in advance of the left, and the operating table tilted to raise the buttocks, the insulated Sims' speculum is inserted into the vagina and the perineum retracted, while the anterior vaginal wall is pressed back by another retractor. The electrodes are now inserted in the edges of the growth, guided by the glass-enclosed lamp illumination, the points being directed in the axis of the pelvis at the location.

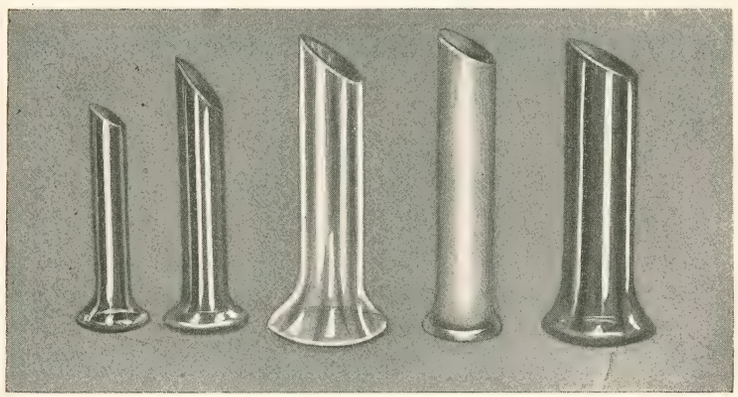


Fig. 126.—Cylindric Glass and Hard Rubber Specula.

With all anodes placed, the cathode is screwed in the central tissue equidistant from the anodes, and the power turned on to 1,000 milliamperes without delay, or to the point of endurance if the patient be not under a general anesthetic.

The results may be viewed by sight as in mouth cases, and the duration of the application guided in the same manner.

Dorsal Position.—The dorsal position, while not permitting as complete guidance by sight as the Sims', permits the anodes to be inserted by touch and without a speculum for the moment, the speculum being slipped over the wires and anodes after their insertion and while they are held in position rigidly. The largest glass or hard rubber speculum that can be readily inserted is selected. After it has been carried by the proper back-and-forth

turns on its longitudinal diameter, the parts are viewed by the glass covered lamp and the cathode screwed into place by sight.

Illustrative Case.—*Advanced Carcinoma of Cervix Uteri. Minor and Major Direct Current Coagulations.* Housewife, aged 45, referred by Dr. Charles Hoffman, of New York. The patient had become irregular in the menstrual function ten months before admission, supposedly due to the menopause, and had noticed an unusual leucorrhea during this time. Six months ago she had an unprovoked hemorrhage from the vagina, and a diagnosis of inoperable carcinoma of the cervix was made by her medical and surgical attendants. She had had some treatment by radium.

Examination on admission showed by abdominal palpation a tumor mass above the pubes. Vaginal examination disclosed a decomposed, friable mass in the site of the cervix the size of a lemon, adherent to the bladder and surrounding tissues, which they had deeply eroded. The general health was poor.

September 5, 1914. Bipolar coagulation under hypodermic injection into the arm of a quarter of a grain of morphia, 400 to 500 milliamperes for forty minutes, with little or no sensation of pain on account of the broken down condition of the operative field. This arrested hemorrhage and lessened the odor, which latter ceased on separation of the slough, with slight hemorrhage, six days later.

September 12. Minor unipolar ionization, 200 milliamperes for half an hour to diseased edge of wound.

October 22. Another minor application having been painful at 60 milliamperes, the patient was given morphia again and a bipolar application of 400 milliamperes made for thirty-three minutes.

The patient returned to her home later with what appeared to be a healthy ring of scar tissue that barely admitted the finger at the upper end of the vagina. This cavity communicated with the bladder, indicating a vesicovaginal fistula. Her general health was greatly improved, and the local parts so apparently free from disease that she was referred to Dr. Herman J. Boldt the following year with a view to repair of the fistula. Dr. Boldt's report was as follows:

"The cervix has, to a great extent, been destroyed by your excellent electrolysis work. I find carcinomatous infiltration extending far into the parametria, too far, I think, for removal. The electrical destruction as seemingly done by you undoubtedly eradicated the disease locally as far as the electrode was active, so that symptomatically the patient was benefited."

A panhysterectomy was done in August, 1915, by Dr. Boldt, with some benefit. The patient was alive when last heard from, a year later.

OPERATIONS ON THE RECTAL AND ANAL REGIONS

When malignant growths are diagnosed in the anal region, or in the lower half of the rectum, before the glands in the pelvis or abdomen are invaded, much reliance can be placed on electrocoagulation methods, if these are boldly applied, as a hopeful method of eradication. Complete inclusion of all diseased tissue in the thermic action is probably more easily and safely accomplished at this site than elsewhere in the body except the limbs, no important vessels being encountered in the anal region and lower rectum that are not terminal branches, and diseased portions of the sphincter being freely included in the action whenever necessary to save life. The failures to cure in the experimental stage of the method were all due to incomplete destruction of the disease and not to hemorrhage. When the growth involves the whole caliber of the rectal tube an artificial anus should be established in the left groin prior to or at the time of operation.

Instruments Required.—For growths entirely within the rectal cavity one or more smooth-edged hard rubber retractors will be needed to shield the opposite wall of the rectum from the heat and current, while all anodes and the single cathode should be insulated to their active surfaces. For external anal growths the anodes do not need insulation.

Operative Details.—General anesthesia is always required in this region. The anodes are inserted in healthy tissue well beyond the growth, and the cathode in its center, as described elsewhere. When the growth is entirely within the rectal cavity the cathode may be held against its center, guided by the gloved finger, replaced before the power is turned on by a retractor, so placed that it will shield the opposite wall.

Illustrative Cases.—Case 999. *Recurrent Adenocarcinoma of Rectum. Major Unipolar Operation.* Mrs. Y., aged 69, was referred by Dr. Dunning-Rose, of New York. The patient had what was supposed to be hemorrhoids for four years. Six months ago a growth, diagnosed microscopically as adenocarcinoma, was removed by excision, including the greater portion of the lower rectal wall. One week ago Dr. Dunning-Rose discovered a recurrence.

Examination on admission showed six nodules about the size of marbles in the line of the incision three inches above the anus on the anterior wall of the rectum, with an indurated mass at the rectal edge. The growths are ulcerated and proliferant.

September 6, 1909. Major unipolar ionization, 400 to 900 milliamperes for a little over a half hour, eight anodes being used. The result was excellent except for an opening in the rectovaginal wall through which most of the feces pass.

June 3, 1910. Dr. Dunning-Rose reported that the patient is free from the disease and had gained twenty-two pounds in weight. The fistula was somewhat smaller.

Case 772. *Carcinoma of Anus and Vulva. Major Unipolar Operation.* Miss Z., aged 49, referred by Dr. Marie Formad, of Philadelphia. Four years before admission a lump the size of a pea appeared on the vulva. It increased in area steadily and finally ulcerated, and two years later Dr. Formad sent her to a hospital where a microscopic examination was made and the case pronounced inoperable. During the past two years the increase in the growth has been rapid.

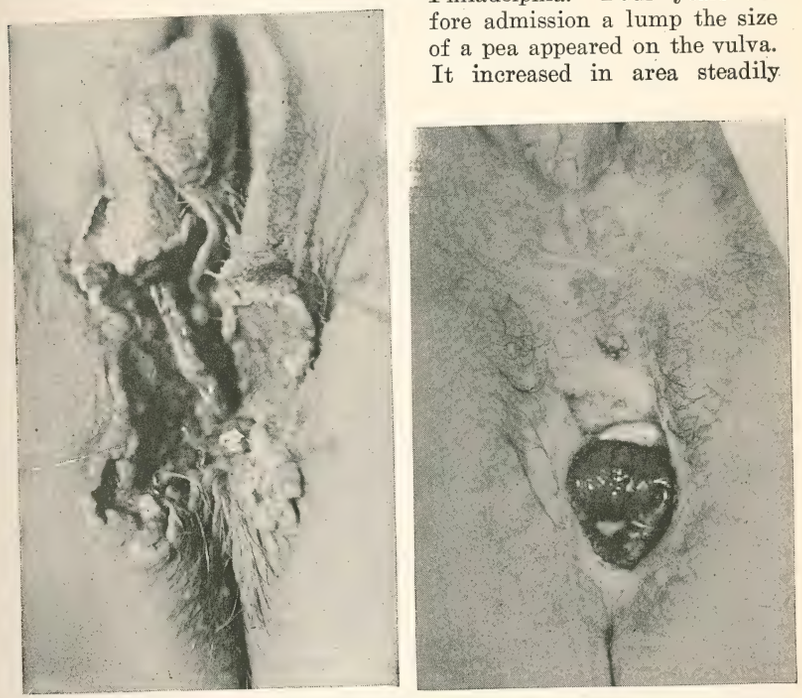


FIG. 127.—Case 772 Before and After Treatment. There is loss of sphincter action, and the healthy rectal mucosa projects somewhat in the photograph at the right.

The condition on admission is shown in the photograph, Fig. 127, kindly taken by Dr. Longenecker, the disease extending from the clitoris to a point around and beyond the anus, involving the whole

vulvar surface and extending some distance into the urethra, vagina and rectum. No enlarged glands were discoverable.

June 24, 1908. Major unipolar ionization, 1,000 to 1,200 milliamperes for one hour, with sixteen anodes. On separation of the large mass of devitalized tissue an immense cloaca-like opening was revealed, into which the three outlets coalesced, the cavity extending so far on the right as to reveal the edge of the pubic ramus, which was bare for more than an inch. The wound was painless after a few days and filled in rapidly. By August 18 the patient had regained partial control of both rectum and bladder.

A cystocele that showed itself during the period of recovery was kindly operated on by Dr. Longenecker. The patient remains free from recurrence at the date of writing, twelve years after the operation. The lack of perfect sphincter action is her only complaint.

Case 740. *Carcinoma of Rectum. Major Unipolar Operation.* Manufacturer, aged 63, was referred by Dr. F. H. Morse, of Boston, in 1908. Thirteen months before admission the patient began to have bloody discharges from the rectum, mixed with mucus, and eight months before pain appeared and has grown worse to the present time. During this time constipation increased until only powerful saline cathartics can induce movement. The patient is normally sallow, but of late is much more anemic and apparently cachectic.

Examination of the rectum by touch revealed a growth two inches from the anus consisting of an annular proliferation surrounding the rectal caliber and of a total dimension equal to a small hen's egg. The inner surface of the growth was eroded, bled easily and gave rise to a foul discharge. The growth was movable, with apparently no attachment to the pelvic wall. The central passage through it which gave exit to the feces when liquid would not admit the tip of the finger. Microscopic examination of a specimen taken at the time of operation showed the growth to be a carcinoma.

April 15, 1908. Major unipolar ionization, 400 to 600 milliamperes for thirty-five minutes. The operation was followed by greater freedom of movement of the bowels, but the catheter had to be used to empty the bladder for nine days. Examination by touch at the end of three weeks showed an open tube at the site of the growth with soft folds of mucous membrane at the edges of the wound. The stools were formed. At the end of three months a decided stricture had formed at the site of the wound, the parts showing no disease by touch or proctoscope. Three years later the patient was in good health except for the stricture. (An artificial anus was indicated in this case.)

Case 76. *Recurrent Epithelioma of the Rectum. Major Unipolar Operation.* Mrs. J. H., aged 57, referred by Dr. H. R. Swayne, of

Philadelphia. Two years before admission she had been operated for cancer of the cervix uteri by excision. The present growth is of unknown duration, a specimen having recently been examined by a pathologist and pronounced epithelioma. The growth was the size of a horse-chestnut, situated on the posterior wall of the rectum about three inches above the anus.

May 4, 1904. Major unipolar ionization, 500 milliamperes for one hour with one electrode. The convalescence was marked by a hemorrhage that was readily checked by the injection of Monsell's Solution. Convalescence was without further incident, the eradication of the disease being complete. The patient was still free from recurrence when last seen, in 1917.

Case 66. *Postrectal Sarcoma. Two Major Unipolar Ionizations.* Mrs. C. A., aged 26, of Royersford, Pennsylvania, applied for treatment October 1, 1903, with a hard tumor nearly filling the lower pelvis, examination by the vagina showing it firmly attached to the posterior wall of the pelvis.

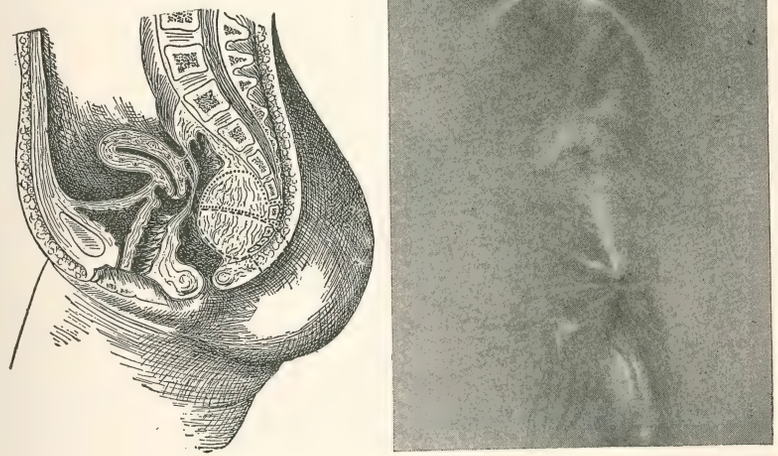


FIG. 128.—At Left, Diagram Showing Situation of Growth, in Case 66. At Right, Photograph Showing Present Appearance of the Final Scar. In the photograph the anus is seen below and the scar above. The final point of healing of the fistula is seen midway between the two.

She had had two confinements, which were terminated by instrumental delivery, both children dying in childbirth, and a more recent confinement terminating seventeen months before being seen, in

which the child was delivered normally and was still living. The tumor was not discovered until March, 1903, when the baby was eleven months old.

The progress of the growth was noted by her physician for several months, and she was finally sent to a Philadelphia hospital, where an opening was made in the median line of the abdomen and the wound closed without effort at removal of the growth.

October 5, 1903. Major unipolar ionization in the shape of a modified Kraske operation was done by electrothermic action, two long anodes being thrust into the tumor from a point several inches above the anus, with a view of making an artificial opening through the coccyx and thus saving the uninfected sphincter. As this was before the development of the bipolar technic the unipolar was used, necessitating a current of 1,000 to 1,600 milliamperes for three hours, with severe burns under the cathodic pad. After the separation of the slough, accompanied by a sharp hemorrhage from a vein under the skin, an examination showed that only one half of the growth had been destroyed.

A second unipolar ionization was done on the remaining portion of the tumor a month later, after the entire coccyx had been lifted from the wound.

The feces were passed through the artificial opening until January 13, and a portion until the following spring, when the opening had greatly contracted. A year later the opening closed entirely.

The patient remains in good health at the present writing, nearly twenty years after treatment. (Fig. 128.)

OPERATIONS ON MALIGNANT GROWTHS IN MISCELLANEOUS SITUATIONS

Case 1468. *Recurrent Sarcoma of Dorsolumbar Region. Major Direct Current Coagulation.* Laundryman, aged 36, was referred by Drs. J. R. Hedley, of Philadelphia, and W. J. Harmon, of Trenton, New Jersey, May 6, 1920, with the large tumor projecting from the middle of the back shown in Fig. 129.

When the patient was a baby he is said to have been struck on the back, a tumor appearing later at the site of the injury. At the age of fifteen years this tumor was removed by excision. About ten years later a recurrence was observed. It grows slowly, has been ulcerated for some time, and bleeds easily. Superficial measurements: 11 by 10 inches. The growth is slightly movable at its base, but the only convincing evidence of absence of connection with the spinal canal is the perfect command of the lower limbs.

August 1, 1920. Major electrocoagulation, strictly bipolar, under ether, 3,000 to 4,000 milliamperes for two hours (had a larger motor generator of direct current been available much more current could have been used, shortening the time under ether). The second photograph was taken after spontaneous separation of the slough, under the ointment treatment. There has been no recurrence at the end of three years.

FIG. 129.—Above, Case 1468 Before Treatment and After Separation of Slough. Below, the Final Appearance of the Scar.

Case 474. *Sarcoma at Site of Abscess Scar in Arm. Major Direct Current Electrocoagulation.*

J. S., aged 41, was referred by Dr. J. Solis Cohen, of Philadelphia, December 6, 1906, with a growth about the size of an apple (Fig. 130).

When seven months old the patient had an abscess at the site

of the deltoid insertion following vaccination. More than forty years later (four or five months ago), the present tumor appeared in or near the scar. It is firm in texture, painless and non-tender, and has doubled in size during the last two months.

December 6, 1906. Major direct current coagulation under ether, 600 to 800 milliamperes for one hour. The large wound healed

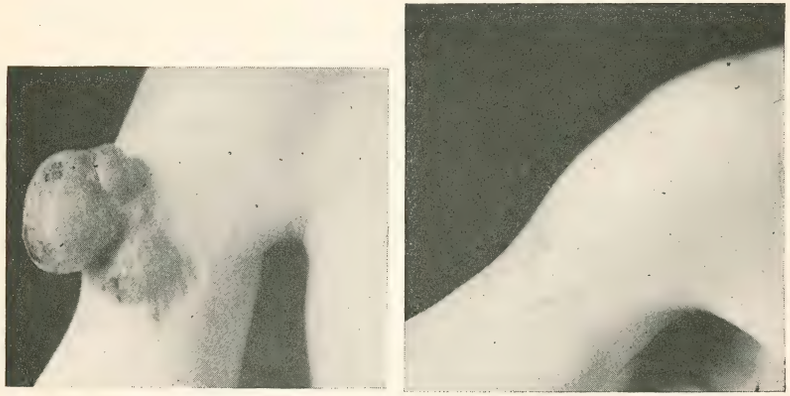


FIG. 130.—Case 474 Before and After Treatment.

readily, with final soft, healthy scar shown in the cut. The patient was sent for twelve years after the operation, and was found to be still free from recurrence.

II. SURGICAL DIATHERMY WITH THE HIGH FREQUENCY CURRENT

ELECTRODESICCATION; HIGH FREQUENCY CAUTERIZATION; ELECTROCOAGULATION

Historical Notes.—The first employment of high frequency arcs in the treatment of cancer seems to have been made by J. A. Rivière, of Paris, France, who reported his work at the International Congress of Electrology and Radiology held in Paris in 1900.[1]

Rivière claimed distinct amelioration of advanced carcinomas by cauterization with the high frequency arc. In 1907 the distinguished gynecologist, Professor Pozzi, reported to the Académie de Médicine at Paris the cure of superficial and even

[1] Esquisses Cliniques de Physicothérapie, Bouchie et Cie., Paris, 1910, p. 283.

of some deep-seated cancers by the action of Oudin sparks. Unfortunately, both Pozzi and Franz Nagelschmidt, of Berlin, who followed later, made their treatment arc even of less value than full cauterization could be in major growths by having it too long—as much as ten centimeters in the case of de Keating Hart, who followed later, and claimed that a destructive effect was not necessary, depending on an "inhibiting" effect only on the remnants of the malignant cells left in a wound after partial removal of an inoperable growth.

It remained for the surgical genius, E. Doyen, of Paris, to hit upon the proper method of applying true destructive electrothermy with high frequency currents, by employing the d'Arsonval current for this purpose in 1907; by 1910 his developed technic was nearly that of present day electrocoagulation in cancer, the term electrocoagulation having been applied to it by him; and it has been described in a sixty-three page chapter in the English edition of his work.[1]

In America electrocoagulation with high frequency currents was first used by G. E. Pfahler, of Philadelphia,[2] and W. L. Clark, also of Philadelphia,[3] the latter of whom first employed minute static arcs to devitalize small superficial growths under the name Desiccation, later finding the minute Oudin arc more reliable for this purpose, and has since done notable work in the removal of extensive malignant growths by a combination of electrodesiccation and electrocoagulation.

Electrodesiccation.—This form of high frequency thermic destruction is strictly unipolar and employs the Oudin current (Fig. 57, page 116) at its weakest. Its clinical indications in the destruction of warts, moles, keratoses and small epitheliomas are those of unipolar electrothermic ionization (page 195), compared with which it often has the advantages of quicker and less troublesome application. Both methods produce about the same smarting sensation, neither usually demanding even local anesthesia unless the situation, such as the conjunctiva, is markedly sensitive. The operator should not allow his hand

[1] "Surgical Therapeutics and Operative Technique," by E. Doyen, English Edition, edited by H. Spencer-Browne, William Wood & Co., New York, 1917, Vol. I, p. 439.

[2] "Electrothermic Coagulation and Roentgentherapy in the Treatment of Malignant Diseases," *Surg. Gyn. and Obstet.*, December, 1914.

[3] "Cancer of the Oral Cavity, Jaws and Throat; Treatment by Electrothermic Methods or in Combination with Surgery, the Roentgen Ray and Radium," *Journal of the American Medical Association,* October 26, 1918.

or arm to come into contact with the patient as both will experience unpleasant sensations. With this difficulty overcome, an electrode adapted to the particular situation of the small neoplasm to be destroyed (the finer the point the better), and a generator that supplies the relatively painless current of short waves (about 100 meters—3,000,000 cycles per second), electrodesiccation is a most perfect method of destroying small neoplasms in a minimum of time, leaving often a scarless spot on the skin or mucous surface.

The immediate effect of desiccation is to turn the destroyed tissue white, by apparently depriving it of fluids. Dr. Clark found, strangely enough, that desiccation of a small growth may be done through a thickness of dry white paper without discoloring the paper, and demonstrates this phenomenon by desiccating a small spot in a piece of soap covered with paper. The paper is not charred or burned, while the soap beneath shows a small crater filled with a whitish powder.

The Oudin current employed in desiccation is of course not passed through a meter as the volume is too small to register on those available. The power applied at the tip of the electrode is gauged entirely by cutting down the spark gap to the minimum and leaving in resistances at the controller at the beginning of the application, and increasing the spark gap during the application as desired. A beginner should test the spark to be used by applying the point of the electrode for a moment on the back of his hand.

Desiccation Electrodes.—Electrodes are sold that are inappropriate to this work and to high frequency cauterization, being too heavy, with an unnecessary, shock-producing current break, and with metal so exposed as to shock the operator. The original of the type shown in Fig. 131 was improvised by the author from a glass medicine tube slightly shortened, bent and tapered over the flame of a Bunsen burner, with the tip of a piece of fine copper wire projecting one or two millimeters beyond the tapered end as active point. The other end of the wire was turned into a loop for attachment of the conductor, and a slender test tube was attached at this point with fused sealing wax to act as a handle. Such an instrument is very light and well insulated except at its tip and connection point, with handle entirely insulated. After cleansing in water it may be resterilized with the heat of the flame. It may be employed also for high frequency cauterization with stronger currents.

To further lessen the chance of accidental sparking between the conductor from electrode to generator and patient (for high frequency conducting cords cannot be really insulated by any practicable covering) I employ the fine wire elsewhere described in this work, No. 25 to 30 double cotton-covered soft copper

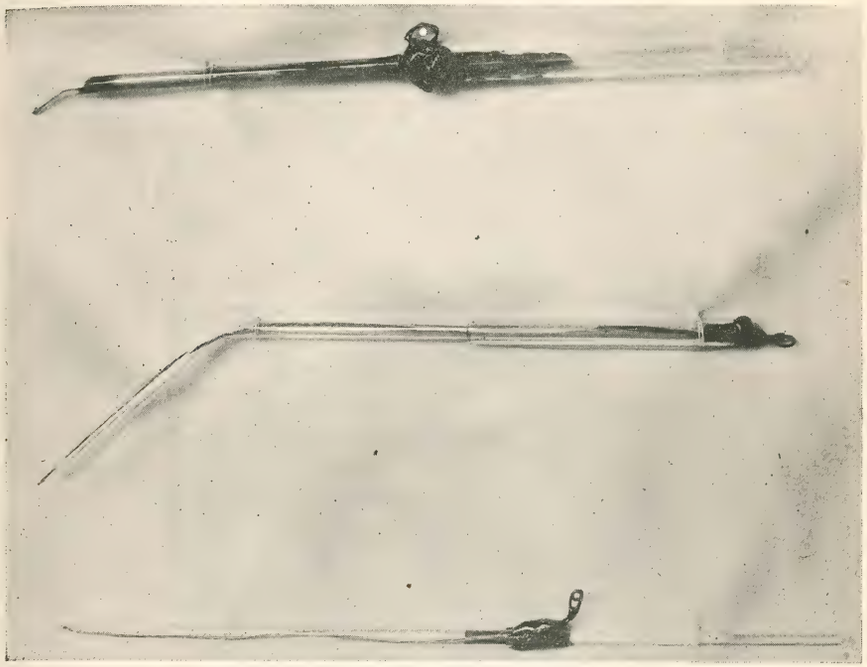


Fig. 131.—Electrodesiccation Electrodes. These may be made of glass tubing enclosing a fine wire, sealed in place by sealing wax. The upper and lower electrodes in the cut have glass handles extending beyond the point where the wire from the generator connects with it. In each instrument the active point is a fine wire. They may be used either on the surface or within cavities.

wire, as the conductor between the electrode and the reel on the Oudin terminal, and see that, if not suspended in air, it rests on thick clothing or dry Turkish towels.

The electrodes shown in Fig. 131 may be as readily used for an external growth as within a cavity, the essential being a fine point on an insulated handle. For use within the vagina the insulated conductor should be long enough to obviate the

possibility of contact of the conducting attachment end with the vulva; and of course the tongue and lip retractors in mouth cases and the speculum in vaginal cases should be of either glass or hard rubber.

With the patient sitting or lying on a couch or nonconducting table, or the limb resting on a nonconducting surface, and with all current turned off, the electrode tip is brought into contact with the neoplasm and the weakest current is turned on by the assistant. The point of the electrode is now raised a trifle from the surface of the growth and the current allowed to flow. As the point of application whitens the electrode may be moved to another spot, and the current increased by the assistant if not too painful. Should the patient shrink or move the current may be instantaneously lessened by resting the electrode on the tumor surface, the power ordered off and the application recommenced. Within cavities special effort should be made to retain proper contact of point and neoplasm, and to retract healthy parts to prevent slight burns to surrounding structures.

After Treatment.—Very small growths may be left to heal by scabbing and without after attention, except the periodic examination of the healed scar that should follow all applications to growths of any degree of malignancy, and the later examination of the scar of a benign growth to see if all has been destroyed. Larger growths should be curetted, if on the external surface, and an additional application made at once if the destruction does not appear to have been carried deep enough, after which a covering of collodion may be applied.

High Frequency Cauterization.—High frequency cauterization is merely an intensification of the desiccation process, when the growth to be destroyed is a small skin epithelioma that is manifestly malignant, yet too small to demand electrocoagulation. In the paper covered soap experiment described above, if the power is increased beyond the limits of desiccation the paper will catch fire, the soap melt, and later char. Like desiccation, it is strictly unipolar and may be merely an intensification of the Oudin current, or, when we wish a still hotter arc, the Tesla, Fig. 58, page 117, which is of course more painful. It gives no meter reading on the meters furnished with the usual apparatus. With a strong, short arc charring or carbonization of the *surface* of the growth occurs after a few moments, and, though this may be carried quite deeply into the tissues by renewing the application after curetting the crust away, the high resistance presented by the charred tissues to the current after the first few moments renders the application effective only near the surface. High frequency cauterization is to be recommended only, therefore, in the smallest epitheliomas and benign growths in preference to zinc ionization or electrocoagulation. Local anesthesia is usually necessary. The mode of application is that of desiccation with a stronger current.

Electrocoagulation with the High Frequency Current.—This valuable method of devitalizing and sealing off *in situ* an accessible malignant growth that is apparently without metastatic colonies, or in which the gland colonies are accessible to similar destruction, employs the metered d'Arsonval current (Fig. 59, page 118). The current is always applied in one or the other bipolar manner, that is: both poles are applied to the patient. In large growths the method of bipolar application may be somewhat similar to that described as employed in the direct current bipolar operation, page 204, *provided the two conducting wires and electrodes are kept far enough apart to prevent short circuits.* In smaller growths, and also in large growths in the hands of some operators, the practice is to employ one active electrode in the growth and a large, indifferent electrode beneath the patient's back or on other convenient surface. The question which of the two plans of bipolar application suits a given case is best decided by the skilled surgeon. It involves, aside from questions of convenience and quickness of effective destruction, that of the vital importance of the character of the immediately surrounding normal tissues in a given case, and their possible reaction to the still intense current heat as it becomes diffused beyond the peripheries of the growth when passing to an indifferent electrode plate, as compared with the direct journey between two electrodes inserted just beyond the outer opposite edges of the growth. Two to four thousand milliamperes of current might be dangerous if passed in concentration through the heart in an application to the left breast, or through the poorly conducting lung tissue (resulting in higher local heating) in applications to either breast, while but little current would traverse either organ when both electrodes are applied directly to the growth.

Current Strength.—Three thousand milliamperes of the d'Arsonval current have repeatedly been applied by the author with the active pole in tumor—indifferent pole on back arrangement, with only reddening of the skin beneath an accurately

adapted indifferent plate, and Doyen states that he has used as much as 15,000 milliamperes. But it is evident that when any such current as claimed by Doyen is used both poles should preferably be in the growth. In this arrangement of the electrodes the more current the quicker and more thorough the effect, *provided the electrodes are kept in contact with moist tissue.*

The proper strength of current to be used in a given case depends, of course, on the size of the growth and on the area of active electrode surface in contact with it. The larger be either of these factors the greater the need of amperage. One should use enough in any case to bring the tissue quickly to the boiling point.

Source of Current.—The high frequency generator employed for this purpose should be one with a transformer and d'Arsonval helix adapted for a large output and a spark gap that produces the shortest waves—that is: the greatest number of oscillations per second, or around 3,000,000 cycles per second.

Active Electrodes.—The rôle of the active electrode in electrocoagulation is *the maintenance of the greatest concentration of current in the growth possible, short of the excess concentration that chars.* The size of the contact area of the active electrode will vary, therefore, with the size of the growth to be destroyed, or, putting it in another way, with the amount of current to be used.

Doyen, judging from his demonstration witnessed by the author in 1910 and the description in his work dated 1917, used unnecessarily large active electrodes, hence the very large currents reported by him—possibly made necessary by too much diffusion at the point of action.

A contrary mistake has been made by some operators in the employment of a needle-like active electrode for a growth of large size. With such concentration at the needle point the coagulation is quickly merged into an arc through charred tissue, making it necessary to plunge the needle ever further to maintain a moist contact with its surface. This is clearly shown by the action of the meter index, which falls as soon as the tissue becomes charred, the current rising only after better contact has been made. Such variations of current are undesirable and time wasting, and cause a portion of the operation to be changed into arc cauterization.

To maintain the proper proportions of active surface for

growths of various sizes and in various situations one should have a number of electrodes of various sizes. Those made with various tips to be screwed to a universal handle are not desirable. Glass insulated electrocoagulation electrodes (Fig. 132) are simple, inexpensive, light in weight, well insulated and easily sterilized. They may be made of glass tubes of suitable sizes and lengths into which is inserted a strip of metal. This

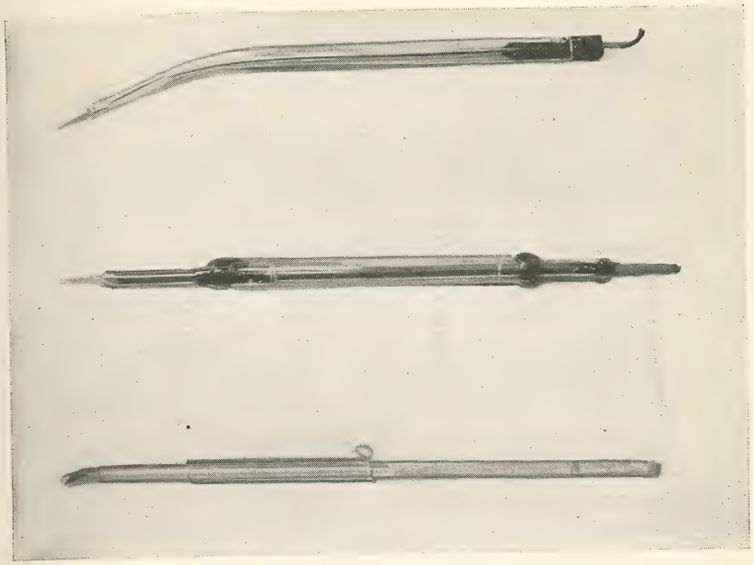


FIG. 132.—High Frequency Electrocoagulation Electrodes (about one-third size). These are larger than the desiccation electrodes and made of stouter materials, either metal strips or picture hanging wire. The exposure of the active metal tip may be varied to suit the depth of growth by warming the wax over the blue flame, and they vary in width.

metal projects from one end as the active tip and from the other as a loop for attachment of the conducting wire. Into the tubes in one type shown, a longer piece of glass is fitted, alongside the metal strip, wedging the whole firmly together and forming a handle. A complete electrode is thus built up of a glass tube, a strip of metal which may be made to project more or less beyond its insulating cover to act as active tip, and a glass rod that fits into the tube as a handle. If the fit is not tight a little sealing wax may be fused on, and when one wishes to

increase or lessen the projection of the metal beyond the glass sleeve a slight reheating will permit it.

The conducting wire, a sufficient length of No. 28 or 25 B.&S. gauge soft double cotton-covered wire, is bared at the ends and firmly attached to the electrode and to one terminal of the d'Arsonval circuit by twisting the wire about each, or with very heavy currents it may be better to use the reel wire itself.

The Indifferent Electrode.—The indifferent or dispersing electrode, when used, is as large as can be accurately fitted to the back, and may be a kaolin pad with large, soft metal backing (page 21), or plain smooth metal, soft enough to conform to the skin and with all wrinkles smoothed out and the edges turned away from the skin. Lathering the skin beneath the plate with soapy water will improve the contact and usually equal the dispersing effect of a pad. The plate is connected firmly to the other terminal of the d'Arsonval circuit by another piece of wire; the meter, of course being included in the circuit, either between the active electrode and its terminal or the plate and its terminal as most convenient.

What happens to these conducting wires during the operation is important. They should be so supported or disposed as to make accidental short circuits by touching each other or by coming too close together, impossible, as this will result in fusing the meter mechanism and putting it out of commission. Should the wires come too near the patient, operator or assistant, a scorching shock will be produced, or if too near a metal table or chair the current will be dissipated to it. A good precaution is to cover all portions of the patient possible with a rubber sheet.

Details of Operation.—While small growths in insensitive situations may be coagulated in a minor operation, under local anesthesia, the destruction of large growths and of those in highly sensitive areas should be regarded as a major operation and should be done under general anesthesia.

The nature of the general anesthetic is important. If ether be employed it should be administered in another room, or removed from the operating room before the current is turned on, as it is liable to catch fire or explode. As, with adequate current available, the largest growth may be destroyed in a few minutes, the current may be turned off and ether readministered from time to time.

With the apparatus arranged as described and all current turned off, application to a sessile growth is begun by inserting the active electrode into it and having an assistant turn on the current gradually. Devitalization, shown by a change to a horny color, begins at once. The current is liable to lower at the meter as devitalization and drying occurs, when the electrode should be moved to an adjoining spot, preferably without breaking contact, until the whole growth appears to be coagulated.

The progress of inclusive devitalization at the external edges is manifest to the eye. Whether sufficient devitalization has occurred at the base is a question for skilled judgment, controlled by the knowledge that the deepest coagulation occurs *in the direction of the opposite pole, and that any undestroyed tissue at the base may be re-treated intelligently as soon as the overlying dead tissue has been cut or curetted away.*

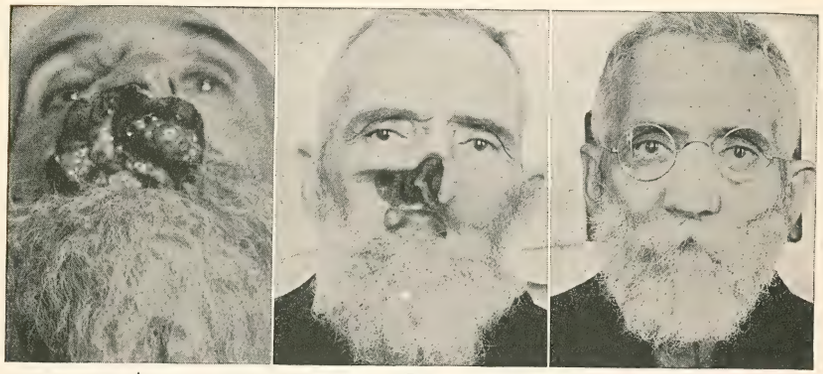
On the completion of the coagulation of the manifest parts of the tumor the dead mass is curetted or cut away and the current re-applied to the base, if signs of insufficient destruction of the diseased tissue then appear. Should the curettage cause bleeding, a reapplication at the bleeding point will cause instant sealing of the vessel.

In growths in organs capable of being materially retracted away from surrounding vital tissues, as the tongue and breasts, a stout ligature should be passed through the growth before the application is begun. With the organ thus retracted, the current may be limited strictly to diseased tissue by employing the true bipolar technic, as in direct current electrocoagulation (page 204), one electrode at the base, passing gradually around the growth, while the other pole is held against its apex or middle. The retraction assists also in the usual, single active pole plan, permitting the base to be directly attacked.

Within cavities, such as the mouth and vagina, the field of operation should be fully exposed by retractors made of insulating material. Doyen used Sims-like specula made of wood, but this material is too slight an insulator, particularly when soaked with moisture, aside from the difficulties in maintaining asepsis. Excellent retractors may be made of hard rubber (Fig. 113, page 235), of various sizes and rigidities by soaking thick strips of hard rubber in hot water, bending them to the curve desired and fixing the curve by immediate plunging into cold water. The glass-enclosed miniature lamp retractor employed by the author in similar bipolar cavity operations with the direct

current (page 236), is liable to be burned out when used so near the high voltage electrode.

Electrocoagulation operations on the base of the tongue and on the superior maxilla (for bone is readily devitalized by both direct current and high frequency electrothermic methods), should be preceded or followed by ligation of the lingual or the external carotid artery on account of the danger of secondary hemorrhage, which may occur between the twelfth and twenty-second days after operation. Dr. Clark suggests such ligation on the tenth day after operation, as sufficient time will then

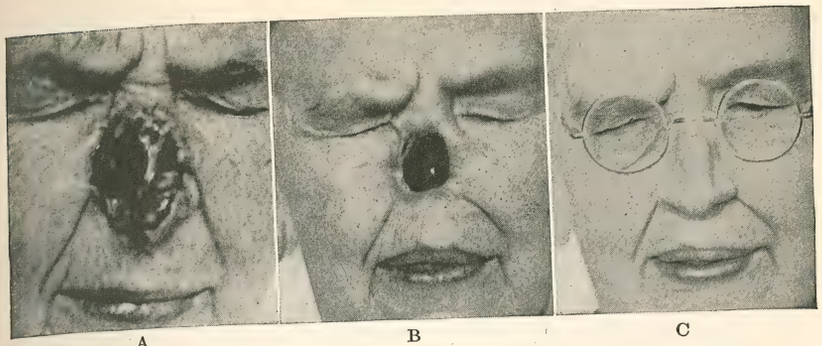


A B C

FIG. 133.—A, Basal-cell Epithelioma Involving the Upper Lip, Alveolus, Hard Palate, Nose, Septum, and Antrum. B, Result of Electorcoagulation Treatment. No recurrence in three years. C, Reconstructed Features by the Sculpture Method. (William L. Clark, M. D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)

not have elapsed before separation for the formation of full collateral circulation. Extensive operations in the tonsillar regions are contraindicated owing to the nearness of the internal carotid artery.

In extensive operations within the mouth it may also be wise to perform a tracheotomy at the time of operation, both as a convenience at this time and a precaution against insufflation of blood clots should secondary hemorrhage occur. Tracheotomy may be done easily and bloodlessly with the cautery knife (page 61), the cauterized edges of the wound being an advantage when a tube is to be worn for some time, and presenting no detriment to later spontaneous closure of the opening when the tube is removed finally.



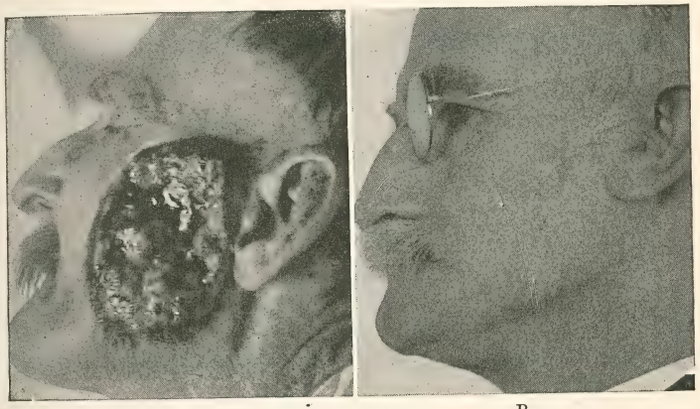
A B C

FIG. 134.—A, Basal-cell Epithelioma of the Nose. B, Result of One Electrodesiccation Treatment. C, Artificial Nose by the Sculpture Method. (William L. Clark, M.D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)

After Treatment.—This is quite similar to that described after the several direct current electrocoagulation operations in the first section of this chapter.

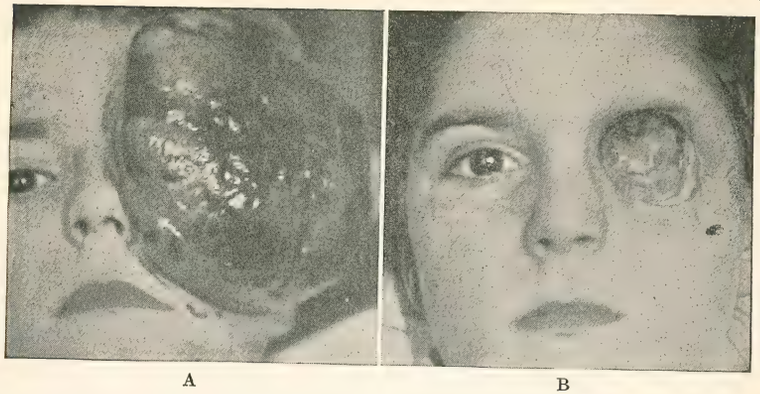
Illustrative Cases.—The cuts, Figs. 133 to 141, illustrate the work of Dr. Clark.

Technic of High Frequency Cauterization of Bladder Tumors and Ulcers.—Benign papillomas of the bladder have been



A B

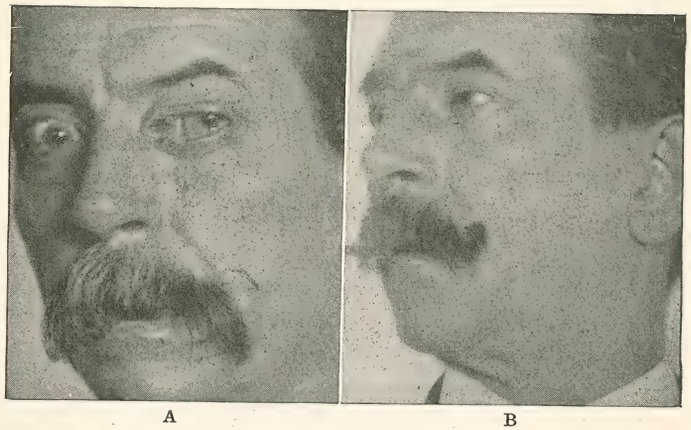
FIG. 135.—A, Advanced Basal-cell Epithelioma of the Cheek and Involving the Bones. B, Result of One Electrocoagulation Treatment. No recurrence in two years. Note regeneration of tissue and absence of contracted scar. (William L. Clark, M. D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)



A B

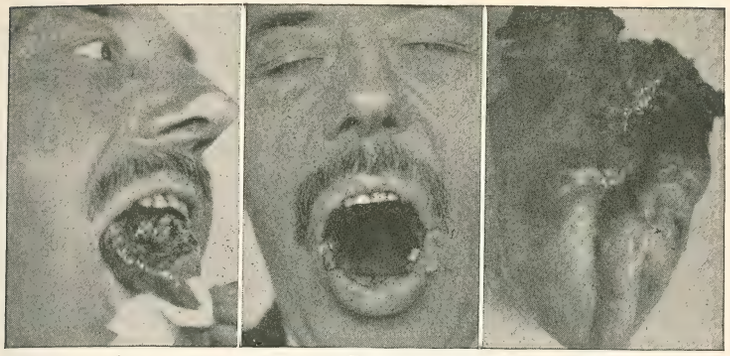
FIG. 136.—A, Glioma of the Optic Nerve of Five Weeks' Growth, Following a Primary Surgical Enucleation, Measuring 20 Inches in Circumference. B, Result of Electrocoagulation, Employing a Snare as the Active Electrode, Then Complete Exenteration of the Orbit by Electrocoagulation, a Long Sewing Needle as the Active Electrode. Condition two months after treatment. Patient died of spinal metastasis seven months after treatment, without local recurrence. (William L. Clark, M. D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)

successfully treated by high frequency cauterization or desiccation through a cystoscope, particularly those of a hemorrhagic nature, and obstinate ulcers may be stimulated into reparative



A B

FIG. 137.—A, Basal-cell Epithelioma Involving the Bulbar Conjunctiva, Upper and Lower Eyelids, Canthus, and Lateral Aspect of the Nose. B, Result of One Electrodesiccation Treatment. Note absence of contracted cicatrix. (William L. Clark, M. D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)



A B C

FIG. 138.—A, Carcinoma of the Tongue. B, Showing Condition After Amputation by Electrocoagulation. C, Another Tongue Amputated by Electrocoagulation. (William L. Clark, M. D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)

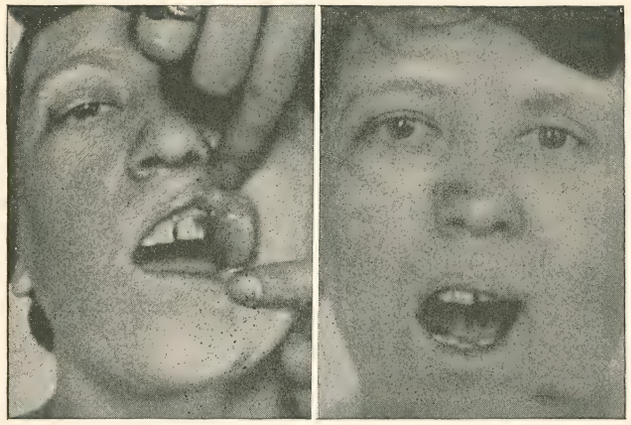
effort. The method was originated by Dr. Edwin Beer, of New York, and applied by him successfully to the eradication of papillomas of the male bladder.

The technical details of the *desiccation of bladder tumors and ulcers in women* are readily carried out by any expert gynecologist familiar with the Howard A. Kelly method of cystoscopy, provided the author's glass Kelly cystoscope be employed. A smaller Kelly metallic cystoscope may be used for preliminary examination of the bladder, preferably at an examination prior

A B

FIG. 139.—A, Epithelioma of the Lower Lip. B, Result of One Electrodesiccation Treatment. Free from recurrence three years. Note absence of contracted cicatrix and regeneration of normal tissue. (William L. Clark, M. D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)

to the actual treatment. Other instruments required are: a Kelly calibrator for dilating the urethra at times; and appliance for removing urine accumulating during examination and just before treatment, preferably a ureteral catheter attached to a bottle reservoir from which air has been exhausted, or other form of aspirator; a suitable headlight for illuminating the bladder, or a very slender miniature lamp with its slender stem covered with thin rubber tubing, to be inserted through the cystoscope into the bladder itself; and a fine, uninsulated wire for desiccating the



A B

FIG. 140.—A, Angioma Involving Buccal Surface, Upper and Lower Lip, Angle of the Mouth. B, Result of Electrodesiccation Treatment Under Local Anesthesia. Note absence of contracted cicatrix. (William L. Clark, M. D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)

tumor or ulcer, about eight inches long, mounted on a properly insulated handle.

One of three positions may be chosen in which to place the patient: Sims' position; the dorsal, with extreme elevation of the hips, and flexion of thighs and legs; and the knee-chest position. The latter is generally to be preferred; it may be maintained for long periods when the patient is allowed to lean against the wall, against which the operating table has been placed; and it permits the maximum of expansion.

To lessen the amount of urine excreted during the treatment, see that the patient drinks no fluid during the several hours preceding the cystoscopy.

Corsets, bands, and all sources of constriction must be loosened, and the patient instructed to breathe freely and gently, not forcing the air from the lungs.

The bladder should be thoroughly emptied before inserting the speculum, and voluntary voiding generally clears it of all fluid. A pledget of cotton saturated with novocain solution is inserted into the urethra and allowed to remain seven minutes.

After having observed the preliminary instructions regarding the clothing, the pledget is removed, the meatus washed with

A B

FIG. 141.—A, Elevated, Pigmented Nevus of the Forehead. B, Result of One Electrodesiccation Treatment Under General Anesthesia. Note absence of contracted cicatrix. (William L. Clark, M. D., in "Keen's Surgery," Vol. VIII, W. B. Saunders Co., Publishers.)

boric solution, and, the speculum, warmed and oiled, is gently inserted in the meatus. Bear in mind the slight curve to the urethra, and begin the insertion by having the handle slightly depressed and the beak pointing a degree upward. When it has penetrated an inch or an inch and a half, raise the handle half an inch to bring the instrument in the line of the canal and continue the insertion gently until it enters the bladder.

The greatest amount of resistance will be met just before the instrument enters the bladder, and it is here that the patient may complain of pain. The amount of pressure to use is hard to estimate, but is probably two ounces, and this, with an occasional rotary movement, is sufficient to allow of the insertion

of the speculum into a bladder that is tender and irritable from chronic inflammation, with a minimum amount of pain at the time and freedom from after discomfort.

The bladder is now lighted in the way decided upon, the author greatly preferring the intravesical lamp described, and the lesions are located and inspected, the bladder meantime being kept free from urine by the aspirator being inserted. If the position is correct, with thighs perpendicular and all clothing loose, the inrush of air will balloon out the bladder so that most of its surface may be inspected.

The tumor having been located and bladder dried, the urine aspirator is removed, and, with the lamp in position, the electrode is passed through the cystoscope and pressed a little into the tumor. At this moment an assistant starts the gentlest Oudin or Tesla current, which is allowed to flow for a few seconds, being increased if the part is kept well within vision until it turns white. If vision is lost it is best to stop the current, relocate the tumor, and repeat. A total current of ten to twenty seconds is the rule at one operation.

Examination to test the thoroughness of the result should not be made in less than a week; if time does not press, two weeks is better. At this time a second cauterization or desiccation may be done if needed.

Much judgment is demanded in gauging the amount of destruction to accomplish in one application. If the current is too weak or its duration insufficient, a troublesome technic must be repeated many times before eradication. On the other hand, it is easy to overdo the electrothermic destruction, and cause an opening in the bladder wall.

While it is probably best to rest the electrode directly on, or slightly within, a tumor, an ulcer is best treated by fulgurating its edges with the point of the electrode an eighth of an inch from its raised edges and for but a few seconds of time.

The *intravesical high frequency cauterization of bladder tumors in men* is much more difficult than in women, and is necessarily confined to expert cystoscopists, who employ a metal catheterizing cystoscope with a fine insulated wire. Some urologists have varied the work by employing the d'Arsonval current for quicker and more effective devitalization, the indifferent plate electrode being placed on the external surface of the body.

Whether the Oudin or d'Arsonval current be employed, there must always be a risk of short circuits through the thin insulation to the metal wall of the cystoscope. This is the probable explanation of much of the pain that has been reported, though doubtless no other damage was done save the diversion of the current from its proper object.

There is a definite need for the devising of a male cystoscope of nonconducting, noninflammatory material for this purpose, capable of sterilization. Until then, these rather common affections in men are better treated by substituting electrothermic ionization with the low volt direct current. The metal cystoscope may be employed with this current with a minimum possibility of communicating the current to the cystoscope itself. A fine insulated zinc wire is employed as an active anode in a technic quite similar to that of high frequency cauterization within the bladder, except that a large, moist pad is placed on the skin surface as a dispersing cathode, a direct current milliampere meter is in circuit, and a smooth direct current of 20 to 200 milliamperes is turned on without shock and maintained until the growth becomes white, or about two minutes. The pain is not more than a similar destruction by the high frequency current would produce, and the slough is as friable and as easily passed from the bladder as that of the latter current.

In neither case is it wise to continue the current in action if one is uncertain whether the electrode wire is still in contact with the tumor only, for contacts of either current with the bladder wall are painful, and, moreover, likely to produce an opening in the wall.

Bugbie, cited by Victor Pedersen,[1] has recently developed the use of the high frequency current through the cystoscope in the *intravesical burnings of enlarged prostates.* The immediate results have been good, and it may render prostatectomy unnecessary.

[1] "Urology," by Victor Pedersen, Lea & Febiger, Philadelphia, 1919, p. 810.

CHAPTER XIII

ELECTRICITY IN GYNECOLOGY

Historical Notes—Fields for Electric Modalities in Gynecology: To Combat Inflammation and its Sequels—To Restore Muscle and Nerve Tone—To Combat Function and Circulatory Deviations—Arrest of Hemorrhage—Shrinkage of Benign and Destruction of Malignant Tumors—Asepsis—Electrodes—Insertion of Intrauterine Electrodes—Abdominal Relaxation—Amenorrhœa—Anaphrodisia—Anteflexion of the Uterus—Atresia of Cervix—Backache—Benign Tumors of the Breast—Bladder Tumors—Caruncle—Coccygodynia—Cysts of the Cervix—Cystic Tumors of the Breast—Cystocele—Displacements—Dysmenorrhœa—Ectopic Gestation—Endometritis—Erosions of the Cervix—Fibroid Tumors—Gonorrhea—Hyperemesis Gravidarum—Hysteria and Neurasthenia—Menorrhagia—Obesity—Polyps—Postpartum Hemorrhage—Prolapse of Uterus — Pruritus — Retroflexion — Salpingitis — Splanchnoptosis—Sterility—Subinvolution of the Uterus—Superinvolution of the Uterus.

Historical Notes.—The late 'eighties and early 'nineties of the nineteenth century saw a remarkable development of interest on the part of gynecologists in the work of Georges Apostoli, Free Professor of Electrotherapeutics at the Practical School, Paris, France. Surgeons and physicians who were jaded by the great wave of hysterectomy then in its ascension flocked to the Apostoli clinic from all parts of the world to observe his electrical treatment for fibroid tumors and chronic metritis. Apostoli's work had been preceded by that of his teacher, A. Tripier, who as far back as 1859 presented a memoir to the Academy of Science at Paris on "Conjunctive Hyperplasias of the Contractile Organs; of Faradization in the Treatment of Engorgements and Displacements of the Uterus, and of prostatic Hypertrophy," followed in 1883 by his "Clinical Lessons on the Diseases of Women." Concurrently with numerous papers in the medical press, a remarkable number of booklets appeared on electricity in gynecology containing Apostoli's technic in the

treatment of fibroid tumors, of which the report of a large number of cases treated by Thomas Keith of Edinboro, a pioneer in hysterectomy for fibroids, was not the least significant.[1]

These works were by Apostoli, translated by A. Lapthorn Smith in Montreal in 1888; by Thomas and Skene Keith in 1889; by the present author and by H. R. Bigelow in 1889; by Drs. Grandin and Gunning in 1891; by Augustin H. Goelet in 1892, by Franklin H. Martin in 1893, followed by the first edition of the author's second work on the subject in 1898.

The more recent discoveries of the X-ray and radium have attracted renewed interest in the subject, and it is probable that the present interest in electrothermy and the newer rhythmic currents may still further attract the attention of the profession to the use of electric powers in gynecology.

Gynecology a Wide Field for Electric Modalities.—The chief transformations of electric power in the body: ionization, heat and neuromuscular stimulation, present valuable opportunities for remedial service in gynecology for two reasons: (1) infection and subinvolution of the uterus on the one hand and traumatic lowering of the muscular efficiency on the other are peculiarly amenable to these transformed forces, and (2) the lessened surface sensitiveness of the vagina and other parts within the vulvar outlet permits the use of ampler dosage than is possible in many other portions of the body, when the sensitive mucocutaneous junction itself is protected from the current by insulation on the electrodes.

These electric modalities offer distinct help in the changing practice of gynecology now evident, as the wave of interest in

[1] "On a New Treatment of Chronic Metritis," by Georges Apostoli, translated by A. Lapthorn Smith, George S. Davis, Detroit, 1888.
"Electricity in the Diseases of Women," by G. Betton Massey, F. A. Davis, Philadelphia, 1889.
"Gynecological Electrotherapeutics," by H. R. Bigelow, Lewis, London, 1889.
"Electricity in the Treatment of Uterine Fibromata," by Thomas and Skene Keith, London, 1889.
"Electricity in Gynecology," by Egbert H. Grandin and Josephus H. Gunning, William Wood & Co., New York, 1891.
"The Electrotherapeutics of Gynecology," by Augustin H. Goelet, George S. Davis Co., Detroit, 1892.
"Electricity in the Diseases of Women and in Obstetrics," by Franklin H. Martin, W. T. Keener Co., Chicago, 1893.
"Conservative Gynecology and Electrotherapeutics," by G. Betton Massey, F. A. Davis Co., Philadelphia, 1898.

major surgical intervention is being replaced by a wider vision that relegates this important work to its proper place in scientific medicine, and recognizes that the restoration of function without sacrifice or fixation of organs, if possible, is the true goal of effort in this specialty.

Before outlining the most desirable technic in individual affections a few general remarks should be made concerning the appropriate modalities in the several underlying conditions present in this special practice.

To Combat Inflammation and its Sequels.—Since inflammation is now known to be invariably due to microörganisms (and though this has been understood since the early seventies, the knowledge has not always since been acted upon, as witness the belief that in displacements of enlarged uteri the mechanical conditions that followed inflammation were of primary etiologic value), the action of electric modalities in combating these conditions should be closely scanned. Obviously, there are two modes of attacking an inflammation if its etiology is considered: a direct germicidal application of mercury, zinc, copper, iodin or other sterilizing ions; or, if this be impossible of full immediate accomplishment by reason of the inaccessibility of some of the infected structures, the use of modalities that will stimulate the natural defenses of the tissues, the leucocytes and trophic neurons, to an elimination of the disease and its products.

Direct germicidal ionization in its full effect is of limited attainment in the common affections of the uterotubal tract, though clearly the best method of "direct action" possible, for, save in incipient gonococcus infection of the vagina, urethra and cervical canal, the invasion of the deeper glands of the mucosa and of the tubes has carried the organisms too deep for a true sterilization; though the ionization necessary to surface sterilization of the accessible tract would add a measure of the second mode, the stimulation of vital processes, to the remedial effect. If sterilizing ions deeply diffused into the cells themselves of the uterine mucosa cannot reach the full depth of the utricular glands in sufficient strength to sterilize them what other method can? Surely not mere surface applications of drugs with less penetrating ionic action, not to mention gross efforts at removal by curettage, which doubtless reinfects the cut surfaces, though possibly also favoring at times a secondary curative tissue reaction.

Since it is now generally recognized that the major portion of

uterotubal diseases are of infective origin, the selection of the electric modalities in treatment is simplified. Ionization for surface or near surface sterilization and tissue stimulation is important, as stated above. For the deeper effects the choice lies between the wave current stimulation of cell and neuron activities, possibly best accomplished by direct current in the slow sinusoidal wave or by alternating current surges, on the one hand, and diathermy on the other.

To Restore Muscle and Nerve Tone in the Pelvis and Abdomen.—All of the older forms of wave stimulation from electric currents have been important factors in the past practice of electrotherapeutists in the treatment of shortened and relaxed muscles in the pelvis and abdomen, but the recent introduction of rhythmic currents (Chapter VII) has placed these efforts on a scientific basis and added greatly to their efficiency. Repeated contraction stimuli as a mode of increasing the mass and power of a muscle, whether of striate or unstriate fiber, requires that a proper period of relaxation should follow each contraction. This has been understood by some in the past, but the operator could only accomplish it by personally turning the power on and off by hand, with or without reversals of polarity, at the cost of occasional shocks to the patient. The monotony of such work to the operator doubtless resulted in applications that were of insufficient total duration to be of greatest efficiency. These drawbacks have been eliminated by the present motor-driven apparatus, which, when properly adjusted and timed, produce rhythmic stimulation that may be administered for effective durations without fatigue.

Daily or triweekly applications of rhythmic currents are indicated as a routine procedure in relaxations and shortening of the pelvic muscles following the accidents of childbirth, and in ptoses of the muscular organs of the abdomen and relaxation of the abdominal walls. Their applicability before and after surgical repair of old muscle tears causing relaxed pelvic outlet is evident. They should replace operations where artificial tucks are taken in hollow organs. Their chief field of usefulness is, of course, in women who have borne children, and in the intervals between childbearing many women would be benefited by them. They are also indicated in some displacements in childless women.

To Correct Functional and Circulatory Deviations from Normal.—In these general conditions, with a more or less obscure

etiology, several of the modalities are indicated according to the seeming causative factors. Diathermy is of value in disordered circulation, but the direct current may have a more important field in stimulating ovarian function, either directly or through neuron stimulation. This is accomplished by a large ball electrode in the vaginal fornix nearest an ovary and a dispersing pad on that side of the abdomen; and if ionization, with its possible irritation of the vaginal mucous membrane, is not desired, neuronic and glandular stimulation may be obtained by the slow galvanic sinusoidal waves with the electrodes in the position mentioned.

To Produce Immediate Arrest of Uterine Hemorrhage and to Correct Conditions Leading to Metrorrhagia.—How a postpartum hemorrhage may be arrested at once by the attending obstetrician, without special electrodes, in any bedroom possessing an electric light lamp cord supplied by the alternating current is described under the heading "postpartum hemorrhage."

Of more interest to the office worker is the modality most effective for the removal of the causes of metrorrhagia and menorrhagia in the nonparturient woman. Here we rely on zinc-mercury or copper-mercury ionization and the X-ray, the former as a direct corrective of the condition of the endometrium that provokes the hemorrhage.

To Remove, or Cause Shrinkage of, Benign or Malignant Growths.—Cathodic electrolysis, zinc ionization, desiccations, and electrocoagulation are the surgically effective methods of destroying small surface growths in gynecology. Fibromas and myomas of the uterus are approached in a different manner, being, on the contrary, not *destroyed* by electric power, unless actually protruding from the os or from the uterine mucosa in an accessible locality, but caused to shrink by a retrograde metamorphosis. In malignant growths the aim is complete and immediate destruction, together with suspicious surrounding tissue, by one of the electrocoagulation methods.

Aseptic and Other Precautions in Electrical Applications in Gynecology.—As this work is not in any sense a complete treatise on any specialty but only presents the electrical possibilities in each, the office practitioner without special training in gynecology is urged to secure confirmation of diagnoses whenever possible, particularly of the presumptive nature of pelvic tumors. *When such diagnoses are uncertain he should not employ any kind of intrauterine therapy.* Fortunately, vaginal and

external applications are available that may be of value in the presence of reasonable doubt of the exact diagnosis, and these often clear up the diagnosis and give relief without the possibility of producing harmful results—a statement that cannot be made with equal certainty of exploratory laparotomies in the presence of similar uncertainty.

Strict asepsis is imperative in all gynecologic examinations and treatments on general principles, and particularly to avoid the possibility of transmitting gonorrhea or syphilis, either of which may be present at times when not suspected. The physician should wash his hands thoroughly with a hand scrubbing brush and abundant soap and water, paying special attention to the finger nails. A noted gynecologist, called on to address a mixed body of physicians recently, devoted his whole time to the importance of washing the hands thoroughly before touching the patient, recalling to their minds the need of "avoiding the appearance of evil" as well as its substance before patients, many of whom are aware of the special need of cleanliness in these days of better general education. He urged that they rewash the hands in the presence of the patient, and if this is not possible but must be done in an adjoining room, "make a lot of splashing" said the speaker.

Metal and glass instruments and electrodes without insulation should be boiled for a few minutes in a weak solution of sodium carbonate after being scrubbed with soap and water. An excellent sterilizer for the purpose is a porcelain enameled asparagus boiler or a larger fish boiler, either of which may be obtained at house furnishing stores. Gasoline is also an excellent sterilizer for metal and glass electrodes, though an insulated glass electrode should not be used with any gasoline remaining in its air jacket. In fact, no gasoline should be allowed to enter this cavity in the glass electrode.

Metal electrodes with an insulation of sealing wax are thoroughly washed in soap and water and then sterilized over the flame of a Bunsen burner or alcohol lamp.

Metal electrodes with hard rubber insulation may be sterilized by being kept in a jar full of gasoline, or five per cent lysol solution, after being scrubbed with soap and water.

Electrodes Used in Gynecology.—The copper ball electrode, Fig. 142, may be used as the active pole in all vagino-abdominal and vagino-dorsal applications of low volt currents. The author keeps such an instrument constantly amalgamated with mercury,

and employs it with either the direct or alternating currents, without covering and always smooth and bright, for when ionization is slight, as in the galvanic sinusoidal, the chlorin and oxygen ions of tissue electrolysis expend much of their nascent activities on the liquid mercury coating—one of the most attackable of

Fig. 142.—Copper Ball Vaginal Electrode.

metals—rather than on the vaginal mucosa. Mercury ions, with some copper ions, may also be diffused from it to the vaginal and paravaginal tissues when the constant direct current is used. When purchased, the author removes the hard rubber tube insulation of this electrode for the reason that, being used often for mercury ionization and dipped in an acid, the joint between

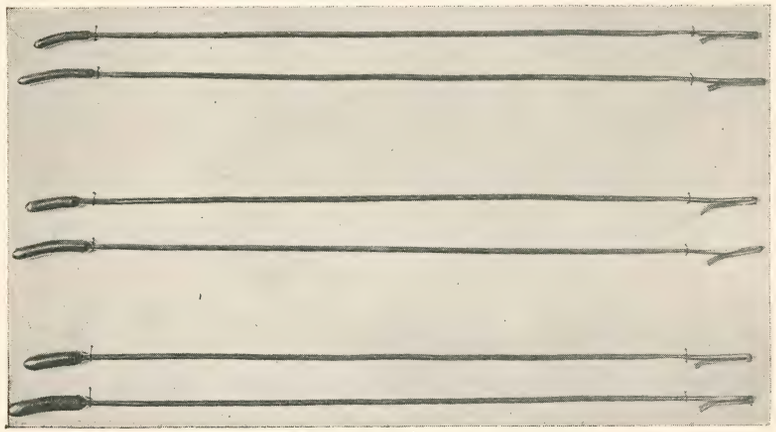


Fig. 143.—Set of Copper Intrauterine Electrodes. The active tips are brazed on the shanks and the connection end of the shanks bent into an acute angle to catch the fine wire conductor. Insulation is by fused sealing wax, applied by heating the shank over a blue flame, melting an end of the wax, and bringing them together.

the shank and the ball should be more fully covered by insulating material than is possible with a tube covering. This is accomplished by recoating the whole shank with fused black sealing wax (Dennison's Black Express Wax comes in pound lots of sticks, and is excellent and inexpensive), this coating being smoothed by reheating over the flame. The ball and the shank

up to the handle is reheated for sterilization and for covering any breaks in insulation before each application. This useful precaution demands but a few moments of time.

Other electrodes for use with the direct current, also insulated with sealing wax and covered with quicksilver when used, are about four sizes of intrauterine electrodes (Fig. 143), one of which may be an ordinary copper Simpson sound with its nickel removed from the intrauterine end by strong acid and insulated with wax along the shank. The conducting wire is attached to it by winding a bared No. 30 wire end around its shank next the handle. The caliber of this instrument is about No. 9, French scale. The others should be about 12, 14 and 20. The olives on these latter instruments *should never be screwed on or soldered in place,* but invariably *brazed* on the shank, since repeated use as an ionization electrode may loosen the tip from the shank.

Fig. 144.—The Massey Flexible Intrauterine Electrode. This instrument should not be employed as the anode of the direct current unless made of irido-platinum.

This cannot happen when the parts are brazed together. These electrodes may of course be used with nonionizing currents also.

A valuable intrauterine electrode, first employed by the author a number of years ago, is the Massey Flexible Intrauterine Electrode (Fig. 144), which, made of its usual material: elastic brass, nickel plated, is a valuable instrument to insert into a cavity without traumatism of any kind, as it adapts itself to the shape of the cavity automatically. It is sterilized by boiling. When this instrument is made of irido-platinum it may be used as an anode.

Electrodes to be used only with nonionizing currents, such as the Morse wave and diathermy, may be nickel plated and hard rubber insulated and should be sterilized by gasoline or the lysol solution.

Vacuum and non-vacuum tubes, the latter advised in cavities only with reservations owing to their liability to breakage, are always glass jacket insulated, and should be sterilized by boiling or a prolonged period of immersion in a sterilizing solution.

The dispersing electrodes are kaolin or asbestos pads. For diathermy they are always thin, pliant metal plates.

Insertion of Intrauterine Electrodes.—In the rare instances in which it is necessary to make an intrauterine application of electric power I have used the technic of Apostoli for many years in the insertion of the instrument into the canal, with a minimum of discomfort to the patient. This method is greatly superior to the method of passing a sound into the uterus through a vaginal speculum, the cervix being held by a tenaculum, for

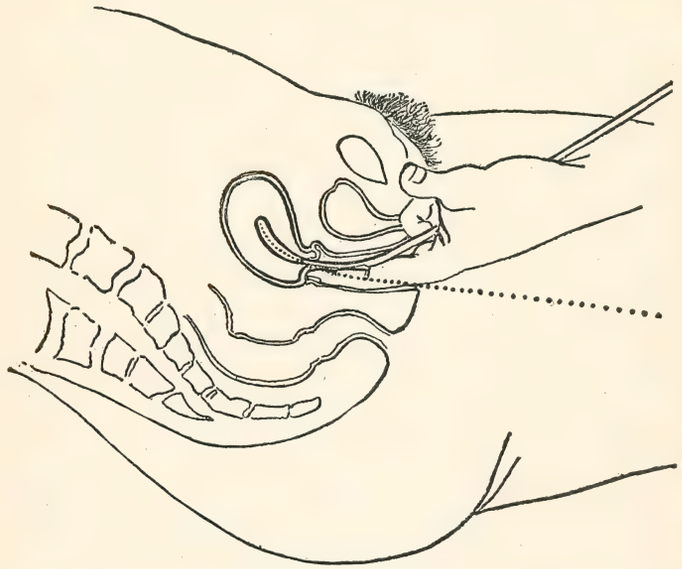


Fig. 145.—Method of Inserting Sound by Touch. The finger is seen drawing the cervix forward. (Conservative Gynecology and Electrotherapeutics, by G. Betton Massey, M. D., Philadelphia. F. A. Davis Co.)

the reason that the educated touch within the vagina coupled with that of the external hand in the bimanual touch, gives a better knowledge to the examiner of the position of the body of the uterus and the direction of the uterine cavity—a knowledge that is lost by the distortion of the speculum, even after the position had been ascertained by a previous examination. The technic, which permits of conforming the electrode to the cavity rather than the cavity to the electrode, is as follows (Fig. 145):

The electrode is first sterilized in the flame and the hands scrubbed. Ascertain the probable curve of the cavity by a preliminary bimanual examination and shape the end of the electrode accordingly, remembering that metal that is amalgamated will break easily. (The mercury may be removed from the copper temporarily by burning it off in the flame.) With the left forefinger locating the os, lift the cervix slightly by the finger under its posterior lip and pass the tip of the electrode along the palmar surface of this (left) forefinger until it engages the os, when the handle is gently depressed curving the tip forward in the line of the cavity, in which it usually glides easily, though there is sometimes difficulty in passing the internal os. If this is not surmountable by patient effort without force, remove the instrument and employ a larger one, as the tip may have been caught on a fold of the cervical mucosa, or, finally a smaller one. The instrument should be held in position by the operator during the treatment.

Such a method has the disadvantage of soiling the instrument with the vaginal secretions, but this is of no possible consequence as proved by absence of ill results in over thirty years' personal use. The condition that is to be avoided as a real menace to the patient is an unclean instrument or finger.

In the following list of gynecologic conditions the electric treatment alone is referred to on account of obvious limitations of space. It is not assumed that the physician will neglect the conjoint or separate use of other appropriate remedies.

Abdominal Relaxation.—See Splanchnoptosis.

Amenorrhea.—Functional Amenorrhea. Failure of menstruation to appear in young girls, primary amenorrhea or *emansio mensium,* is a purely medicinal and hygienic question in the majority of cases, even when one or more menstrual periods have occurred at irregular intervals. The causes, aside from slow maturity, are anemia from constipation and too sedentary habits, and from under-nutrition otherwise produced. If correction of the hygienic faults, an iron tonic, and a half or whole tablet of the Pil. Rhei Comp. of the pharmacopea fail to bring relief, short static sparks may be administered to the back through the clothing, with the corsets removed, followed by the static wave current to the back. In more persistent cases diathermy, with fairly large plates to the abdomen and back, may be of service, or the direct current to the spinal region. Examination of these young girls is not necessary or warrantable unless there have been periodic attacks of pain or other evidence of an actual establishment of the function and a mechanical retention of the

flow, when an abdominorectal examination should be made under general anesthesia to clear up the diagnosis.

Secondary amenorrhea, or *suppressio mensium,* may also be due to anemia, constipation or intestinal stasis; to a change of environment, especially a sea voyage; or to a pure neurosis in an otherwise apparently healthy girl. The ever present possibility of pregnancy should be continually present in the physician's mind. The same measures may be used as in *emansio mensium.* In a number of instances of the neurotic type in the author's experience a few applications of the static modalities have reëstablished the function promptly, particularly the static spark to the back.

Pregnancy excluded and medicinal measures unavailing, we may apply abdominodorsal galvanic sinusoidal waves of 50 to 100 milliamperes, or diathermy with plates in the same location.

Anaphrodisia.—Sexual frigidity in women has been considered so universally by omission in our large treatises on the diseases of women that one would suspect that a function that, when abnormal in one sex has protean possibilities of harmful results, was purely mechanical in the other. It would seem that these special treatises in this respect are like the play of Hamlet with the part of the Dane left out. Anaphrodisia has an important influence on the well-being of a woman living a connubial life, and possibly an even more deplorable effect on her mate.

Of the value of electricity in primary anaphrodisia we have no data. Secondary, or acquired anaphrodisia may be due, among other causes, to ovarian anemia, or to relaxations and lack of power in the pelvic muscles. Both of these deficiencies may be relieved by regular, triweekly applications of the rhythmic currents, with ball or short cylindrical electrode in the vagina and a large dispersing pad on the abdomen, 50 to 150 milliamperes of the galvanic current being used for twenty minutes and 28 or 30 waves per minute. Nongalvanic rhythmic currents may have the same effect as the galvanic. The method has a wide field of usefulness, both as a treatment for the condition itself and also as a building-up exercise for relaxation of the pelvic outlet in parous women. It may be employed without the repair operation in moderate, old tears of the perineal muscles and after the operation in extensive tears.

Anteflexion of the Uterus.—A moderate amount of anteflexion is a natural condition in every normal woman. Extreme anteflexion is also congenital and of itself of no consequence, though

probably as a mal-development a contributing cause of sterility when associated with a small, tapering cervix and a "pin hole" os. For the electrical treatment of these conditions see Sterility.

Atresia of Cervix.—See Sterility.

Atrophic Endometritis.—See Endometritis.

Backache.—The conditions that produce the symptom: backache, are extremely varied and too numerous for full consideration in these pages. A tentative classification would divide them into those of orthopedic causation; of a traumatic plus rheumatic causation; and those due to disordered metabolism. According to Howard A. Kelly,[1] whose opinion is authoritative, few backaches are due to gross, ascertainable diseases of the pelvic organs or the abdominal organs, in spite of the general opinion of the laity, fostered by quack literature, that backaches among women are due to womb disease and among men to kidney disease.

Backaches due to orthopedic faults include those caused by maladjustment of bone and muscle leverage, such as heels that are too high, improper spinal postures, inequalities in the length of the legs, etc., as well as the traumatic backaches.

Traumatic backaches are the acute attacks known as lumbago, generally due to sudden sprain of a ligament in the lumbar or sacoiliac region, possibly at times to a true luxation or fracture. These accidents occur in middle life when the parts are congested and possibly softened by a local accentuation of a general "rheumatic" condition, often associated with intestinal stasis. They are characterized, not by an ache, but by suddenly appearing acute pain, aggravated by motion or a position that puts the tender spot in a strained condition.

The treatment of an attack which appears so suddenly as to suggest a sprain or luxation is threefold: Diathermy, with the patient lying prone on the large dispersing plate and a 4 by 4 inch plate in close contact with the skin over the tender spot, the application to be continued until the tenderness to pressure lessens, when the parts should be put in "splints" as thoroughly as possible by strapping the part while in the prone position with two or three inch strips of zinc oxid adhesive plaster at least 14 inches long, the strips crossing each other at the tender spot with ends radiating in all directions from this center. Eight or ten such strips should be used with their sides lapping. They should be removed every other day, diathermy applied, and the

[1] "Medical Gynecology," p. 233.

part restrapped. The patient should also be given teaspoonful doses of sodium phosphate for the "rheumatic" condition. Such a combined treatment will usually enable a patient to resume activities at once. As the sprained parts will be weak for some time an abdominal belt should be fitted to take the place of the strapping as soon as adhesive strips are removed. Massage or rhythmic currents, the latter with both poles on the spinal muscles, or else applied abdomino-dorsally, will complete the cure and lessen the danger of a recurrence.

The backache of disordered metabolism is more chronic, generally intermittent in character, and often without a tender spot. It is generally located higher in the lumbar region and at times in the dorsal. It is probably a local expression of a general condition, and its treatment demands measures to restore the general health by the detection and alleviation of disordered conditions wherever found. Local treatment may be stimulating applications of diathermy, static wave currents and static sparks.

Benign Tumors of the Breast.—The responsibility of the physician consulted by a woman with any kind of hard spot in the breast of uncertain character is almost as great as when he encounters clinically evident cancer. The probability of any *slowly growing,* non-tender lump in the breast being incipient cancer is greater than with similar lumps elsewhere in the body. All cancers are small at first, and never really painful at this time, *nor are they ever tender at any time.* They grow in appreciable periods of *months,* rather than *weeks,* except in the fulminant type in younger women. In the clinically evident cancer it is easy to transfer all responsibility to the patient herself or to her relatives, but when we are ourselves uncertain of the diagnosis the responsibility for proper action remains with us.

In this difficult position, knowing full well the disaster to patients in a large percentage of cases who follow the advice "don't touch it until you have to" on the one hand, and the undesirability of wounding the breast by the electrothermic destruction of a noncancerous nodule, or amputation of the whole breast and axillary muscles unnecessarily on the other, a careful palpation should be made and the chances for or against malignancy estimated as well as possible. *In no case should the tumor be wounded to secure a specimen for miscroscopic examination unless the patient is on the operating table and the operator prepared to proceed at once to destroy or extirpate,* on account of the

dangers of spreading the growth and of assisting metastasis if it be malignant.

Palpation may reveal that a nodule is a fibroma, but only in our experience when the lump is unusually hard, rounded and slips through the fingers so easily as to indicate that it has a capsule. Recurrence of clearly evident malignant disease has happened in the scars of what had been enucleated by able surgeons as fibromas. The safest treatment for fibroma of the breast is enucleation, followed immediately by electrothermic destruction of the capsule.

Fluctuation in a soft, clearly outlined nodule indicates a cystoma. The cystoma is apt to give rise to a slight pain—more uncomfortable than either fibroma or incipient cancer. While benign, cystomas have been found to have carcinomatous patches in the cyst wall, notably so in a series studied by the late J. William White, and cystic disease in clinically evident cancers of the breast is not uncommon. The safest course is to destroy the cyst wall by direct current coagulation, the walls being pulled out from the breast tissue by tenaculae acting as the cathode and the zinc anodes inserted behind them (page 245). When they are multilocular a separate application is made to each cyst. If many cysts exist in the breast the whole organ should be destroyed.

Chronic lobular mastitis of an indolent character is the most difficult to differentiate from incipient lobular cancer, assuming that no enlarged glands are found in the axilla, for if such are found the case should be assumed to be cancer at once and the primary nodule and axillary contents should be destroyed. The benign condition is more generally found in young single women than in married women—at times in adolescent girls. Palpation reveals no special difference between this condition and incipient cancer nodules.

Electricity is valuable in clearing up the diagnosis in the last mentioned condition by favoring resolution of the benign condition when present, as first pointed out by the author in "Conservative Gynecology and Electrotherapeutics" and more recently in a paper read before the American Electrotherapeutic Association,[1] indicating the value of the faradic current as a test for incipient cancer of the breast.

The test is the application of the faradic current for fifteen or twenty minutes daily to the breast in good strength, the dis-

[1] *Medical Record,* November 10, 1917.

persing pad being beneath the back. In the absence of this modality the static wave current should be equally effective, or the nongalvanic rhythmic waves. Electrothermy, including the tube currents, should also be of service, with the reservation that both heat and the ordinary galvanic applications are both liable to increase the growth of the nodule if it be a cancer. The wave currents are not likely to have such effect.

If the lump be benign it will become smaller within two weeks. If, on the contrary, it does not decrease in size under this treatment, the chances are that it is malignant and should be destroyed at once.

Bladder Tumors.—For the technic of electricity in tumors of the bladder in women see page 279.

Cancer of Cervix Uteri.—See page 256.

Cancer of Vulva.—See page 261.

Caruncle of Urethra.—This little tumor of the urethra, being usually situated at or just within the meatus, is extremely sensitive. For destruction by either zinc ionization or desiccation, the former being at times preferable because of more ready confinement of the destruction to the growth itself, it is anesthetized by placing one or more ear-spoonfuls of cocain crystals directly on the moist tumor itself. At the end of ten minutes nearly complete local anesthesia is produced, the crystals making their own solution by osmosis. The desiccation method has been described (page 267). For ionization employ a very fine zinc needle, insulated with hot sealing wax to leave a length of point bare somewhat less than the depth of the tumor. After insertion it is guyed in position as described at page 151 and a unipolar application of from 2 to 15 milliamperes made until the whole of the little growth has turned white.

Cervical Endometritis.—See Endometritis.

Coccygodynia.—Two conditions are found in gynecologic literature under the name of coccygodynia: the tenderness on motion or on pressure in the seated posture, due to fracture, luxation or rheumatoid arthritis of the coccygeal articulations, readily detected by examination with the forefinger in the rectum and the thumb outside. The other condition is one of pure neuralgia of unknown origin, though possibly due to arthritic deposits at the points of emergence of the nerves from the spinal canal.

Several electric modalities have given good results in both conditions, including formerly the faradic applied

externally. Diathermy is probably the most effective application. Static waves may be applied within the rectum with an insulated olive electrode or by a plate conformed to the surface externally. Rhythmic nongalvanic currents are also indicated.

Constipation.—See also Splanchnoptosis. This protean cause of ill-health is generally accompanied and largely due to atony of the muscular coats of the large and small intestines, except in the rare instances of spastic constipation. Many electrical methods have been used which require an active pole within the rectum, with and without a hydro-electric increase of the size of this pole by injecting normal salt solution through the insulated tunneled electrode. In women an equal effect may probably be attained with a ball electrode in the vagina. In each instance these currents are used with a large dispersing pad on the abdominal wall.

I prefer usually to employ stronger rhythmic currents than are comfortable in these internal applications, passed directly through the intestinal region, with a moist kaolin pad of 7 by 7 inches surface on the abdomen and a larger one beneath the back, the latter with its upper edge somewhat above the level of the lower angles of the scapulae. The latter position brings into action the lateral muscles of the abdominal wall also. Powerful non-galvanic currents may be used, or as much as 100 to 150 milliamperes of the galvanic sinusoidal, both in waves from 11 to 30 per minute. The duration of the application should be from twenty to thirty minutes.

Cysts of Cervix Uteri.—Small nodules projecting from the surface of the cervix, revealed on visual examination to be glistening, pearl like cysts, are retention cysts from occlusion of the Nabothian glands. They are readily eradicated and their secreting walls destroyed by puncture with a long, insulated zinc needle, the patient being in the Sims' position, and zinc ionization with only 5 to 10 milliamperes to each cyst until it turns white. No anesthesia need be used usually. The dispersing pad is placed on the right hip.

Cystic Tumors of the Breast.—See Benign Tumors of the Breast.

Cystocele.—Disappearance of the muscular structures in the anterior wall of the vagina with prolapse of the bladder into this space, due to the accidents of parturition, usually demands an operation for repair. After the operation, or rarely without

it in early and slight conditions of relaxation, rhythmic currents applied with an active olive electrode of large size (Fig. 142), and a 7 by 7 inch pad on the abdomen will be of great service in restoring muscular tone to the parts.

Displacements of the Uterus.—See Prolapse of the Uterus.

Dysmenorrhea.—The value of electric modalities in painful menstruation is more generally recognized since the overthrow of the purely mechanical theories of its causation fathered by Sir James Y. Simpson. These theories led to many unnecessary dilatations of the cervix under the assumption that the cervical canal was too narrow to permit of free passage of the menstrual fluid. According to Kelly [1] it is estimated that the amount of blood lost is one drop in three minutes, and it has been demonstrated that menstrual blood flows easily at this rate through a tube much smaller than any possible stenosis of the os, or of the canal.

The exact causes of painful menstruation will doubtless not be known until we obtain clear light on the exact nature of physiologic menstruation itself, but the association of dysmenorrhea with anemia, constipation and other conditions attending neuroses indicates a circulatory and neural origin.

Kelly (at page 103 of the work cited), discusses electricity among the nonoperative measures for the permanent relief of dysmenorrhea as follows, after citing the opinions and technic of several electrotherapeutic writers of twenty-five years previously:

"The treatment of dysmenorrhea by means of electricity was a subject of much interest some fifteen years ago, and promised to yield most excellent results, according to certain good authorities. The method has failed to fulfill its early promise, not because it has proved untrustworthy, but because there has been a general failure of interest in the question of the use of electricity in gynecology. It seems a matter for regret, however, that the electrical treatment of various gynecological affections should not receive more attention. . . . It is to be hoped that gynecologists, and general practitioners who practice more or less gynecology, will give the use of electricity in the treatment of dysmenorrhea a thorough trial during the next few years, for it would seem to offer a fair prospect of relief in certain intractable cases, though it is still upon probation."

[1] "Medical Gynecology," p. 94.

Almost all the electric modalities have been of service in various hands to relieve dysmenorrhea permanently. This fact indicates that it is by no means necessary to resort to a local examination in young girls or to employ methods of treatment that require insertion of instruments within the vagina or uterine canal. That this has been done frequently by electrotherapists in the past indicates merely that they had not entirely freed themselves from the ultra-mechanical views still unhappily prevailing. While examinations are usually necessary in married women suffering from painful menstruation, they are proper in ordinary cases in young girls only after external methods of application of electricity have failed, or if a really purulent leucorrhea exists. In addition to the cure of the leucorrhea, its intrauterine action is probably to lessen hyperesthesia rather than to dilate.

In association with other indicated remedies, the author has for years employed the direct current with excellent results. This is applied stabile, or without waves, with a 4 by 6 inch active pad in the hypogastric region and a larger dispersing pad beneath the lumbar region, 50 to 100 milliamperes being used daily for fifteen minutes during the week preceding menstruation, including the first day. The treatment is intermitted during the remainder of the period, but for two weeks following it the patient receives galvanic sinusoidal waves of the same strength thrice a week for twenty or thirty minutes, returning during the following week to the use of both applications seriatim. Static sparks to the back are usually added in the premenstrual week. But of late the author has employed abdominodorsal diathermy instead of the galvanic current with equally good if not better results. This is a particularly valuable modality when applied during the actual pain of the first or second day of menstruation.

Should these measures fail after several months' trial, and a case of long standing appear to demand a more direct alteration of the pelvic conditions, the insulated Simpson sound electrode may be inserted as described in page 292 and 20 to 30 milliamperes be applied for six minutes once a week with the intrauterine electrode the cathode. As this procedure does not require the use of a speculum little interference with the hymen occurs.

In younger women this application may be replaced by the rectal application of the static wave current. This was first suggested by Dr. Mary L. H. Arnold Snow, of New York, who describes the procedure as follows:

"The patient in a proper reclining chair or couch on the platform, with the buttocks opposite the positive pole of the machine. A metal electrode about six inches long, which is attached to a vulcanite handle and connected by a wire to the positive pole of the machine, having been first warmed and lubricated, is inserted into the rectum, following its posterior wall. When it has been inserted the handle is moved backward, thus placing the electrode against the uterus. The handle may be inserted between the pages of a very thick volume, so that the electrode cannot be expelled, or it may be held in position by a tape fastened to the clothing farther up the back. The negative side of the machine is grounded to a proper earth wire. The machine is started with the discharging balls closed and at a low rate of speed, the spark-gap being then gradually lengthened according to the tolerance of the patient. In sensitive patients the spark at the spark gap that will be borne will not exceed one inch in length. In these cases at each successive treatment, as congestion and tenderness diminish, an increased length of spark gap can be used as a rule. The duration of each treatment is twenty minutes. If there is a marked retroversion it may be difficult to insert the electrode to its full length at the first treatment, but as the congestion of the uterus is diminished it rises in the pelvis and the difficulty becomes less, so that usually after two treatments it can be readily inserted to a length of four to five inches." [1]

The nongalvanic rhythmic currents may also be used in the manner described by Dr. Snow, with the indifferent pad on the abdomen.

Ectopic Gestation.—The treatment of ectopic gestation, or tubal pregnancy, by devitalizing the fetus before rupture of the gestation sac by strong faradic or galvanic stabile (or constant) applications, and the use of more moderate currents afterwards to promote its absorption, is said to have first been employed by Bachetti in Italy in 1853 and later by Braxton Hicks in England in 1866. Allen, of Philadelphia, used it in 1869, arousing sufficient attention from gynecologists in this country to cause it to be referred to abroad as the American plan of treatment. Its use in selected cases was favored by T. Gaillard Thomas, Munde, B. H. Wells, Brothers and others.

Its employment in this country has greatly lessened since the late eighteen nineties for two reasons: the employment of the method by vaginal electropuncture into the sac in seven reported

[1] *Journal of Advanced Therapeutics,* May, 1907.

cases (instead of using the prevailing cotton covered electrode) with two deaths and five cures, the mortality being far greater than operative removal; and the increasing confidence in the knife operation. As we see it now, so dangerous a method of carrying electric power through a mere centimeter or so of excellently conducting tissue was entirely indefensible in a condition in which a mere arrest of the fetal heart was all that was required of it. It should never have been employed in this manner in any case.

My own experience definitely favors the properly conducted electrical treatment if the condition can be diagnosed before the end of the third month; later than this there is some doubt as to the ready absorption of the product. The proper technic is a vagino-abdominal application of 100 to 200 milliamperes of the direct current, with a ball electrode in the vagina on the side next the tumor and a large dispersing pad on the same side of the abdomen over it. The current should be turned on slowly to the peak, held a full minute, turned off, reversed, and the procedure repeated slowly several times. The faradic current may be used in the same way to a point of strong—not violent—contraction with the cathode in the vagina. The treatment may be applied daily until the tumor shows signs of softening and loss of elasticity, when an expectant attitude is assumed. Meantime the patient should be in bed and at absolute rest, with the constant attendance of a nurse.

Endometritis.—Metritis.—Acute Neisserian infection of the cervical cavity is considered under the heading of gonorrhea. The only other acute forms of endometritis are those found after septic abortion and in puerperal women.

The most important symptoms of acute and chronic endometritis are *a persistent purulent discharge and excessive menstrual flow,* to which should be added a sensation of weight in the pelvis and general discomfort. The uterus is enlarged, subinvoluted if postpuerperal or postabortive; and in those chiefly confined to the cervix, this portion is bulbous and softer to the touch than normal. A chronic endometritis may last for years and be the source of much discomfort.

It is probably true, as stated by some observers, that the seat of the chronic infection of the mucous membrane is more outside the internal os than within it. Whether this be so or not may be gauged by the relative hypertrophy of the two portions of the organ, as estimated by the bimanual touch.

The electrical method of treatment to be described presupposes that a fairly accurate diagnosis has been made, at least accurate enough to put the possibility of pregnancy out of the question and to make it unlikely that a closed pus tube or an extrauterine pregnancy is present. *Any acute inflammatory condition of the appendages also absolutely contraindicates all intrauterine treatment.*

These conditions being rigidly excluded by the best available skill in differential diagnosis, by touch and by a consideration of all of the symptoms, it does not matter so far as the safety and value of the treatment are concerned whether the symptoms and the purulent discharge be due to a subacute or chronic infection of the endometrium, with or without an old laceration of the cervix; an incipient myoma, not yet large enough to be made out; a polypoid degeneration of the cervix; or tuberculosis of this organ. In each case the treatment to be described is of value and generally curative, and free from harmful possibilities if properly applied. It does all that can be done by curettage in all of these conditions and in a more scientific manner, and demands less skill on the part of the operator than the operative procedure. The method advised is that of copper-mercury ionizations, followed at each application by rhythmic waves.

With a warmed cathodic dispersing pad on the abdomen, an intrauterine copper anode (Fig. 143), is selected of a size that is the largest to pass the internal os. This properly insulated as described at page 290, amalgamated with quicksilver, sterilized in the flame, and after being connected with the anodic binding post, is inserted as described at page 292, merely within the cervical canal or within the cavity of the corpus as the diagnosis indicates the cervix or the whole cavity as the chief seat of the disease. Supporting the handle so that the instrument will not move during the application, a direct current of 20 to 40 milliamperes is turned on and maintained from four to ten minutes, according to the severity of the case and the pain produced. The current is then turned off, the wires attached to the rhythmic current apparatus (or the intrauterine electrode is removed and replaced by a ball electrode in the vagina) and a rhythmic current of slow waves employed for fifteen minutes.

The intrauterine application should not be repeated oftener than every five to seven days, but the rhythmic current may be used daily in the intervals with the active electrode in the upper vagina.

Erosions of the Cervix.—These bright red discolorations of the mucosa surrounding the os have been attributed by some to an eversion of the cervix. This cannot be true in some cases occurring in nullipara, where the erosion seems to be due to a corrosive action of a secretion from the cavity. In such cases zinc-mercury ions to the eroded surface and to the cavity are indicated.

Extrauterine Pregnancy.—See Ectopic Gestation.

Fibroid Tumors of the Uterus.—The voluminous discussions of the Apostoli treatment of hemorrhagic and nonhemorrhagic interstitial fibroids in the last two decades of the nineteenth century are now, since the value of the filtered gamma ray is widely recognized in these conditions, of mere historic interest, with the important residuum that it has contributed the most effective means for the direct control of uterine hemorrhage known in gynecologic procedures: viz. zinc- or copper-mercury ionization of the bleeding cavity. The association of this procedure with the X-ray treatment will assist greatly in the prompt arrest of the hemorrhage that is a chief feature of some fibroids.

It is probable that the failure of the Apostoli treatment to achieve a general popularity equal to the present use of the ray, in spite of its nearly one hundred per cent. of successes in arrest of hemorrhage and arrest of the growths, was due to the original practice of the originator in using cathodic puncture as the essential detail of the method, later abandoned by his followers in favor of intrauterine methods, together with a general feeling that it demanded special training and expertness.

It is unnecessary at this time to quote opinions and experiences in favor of the Roentgen ray treatment of properly selected fibroid tumors of the uterus as the current literature is too voluminous. If cases that now require hysterectomy are carefully selected the operation would be a rare one.

The mode of action of the gamma ray, whether generated from the X-ray tube or from radium, in causing a retrograde evolution of these growths is unknown, as is the cause of the growths themselves. My own view is that shrinkage and absorption of the exuberant fibrous tissue is induced by the action of the ray on the growth itself rather than on the ovarian activity; that the cause of the growth may be an organism of a nonmalignant type which succumbs to the ray, just as it succumbed to the more slowly aroused tissue resistance—phagocytosis—caused by the older Apostoli treatment. The practical application of this view

is that the ovaries may be wisely shielded from the ray in treatment whenever this can be done.

Helpful suggestions in the selection of cases suitable for the method are best given by enumerating those varieties in which it is not suitable. All remaining varieties are suitable for the method, with a reasonable expectation of one hundred per cent. of practical cures in the sense of a permanent arrest of hemorrhage and other symptoms, followed by a progressive shrinkage that ultimately makes it impossible for the patient to discover the growth herself, and in a smaller proportion causes its entire disappearance.

Fibroid polyps, whether large or small, are often associated with exhausting menorrhagia. These should be removed by the vaginal route, an exceedingly simple procedure by torsion in the grasp of tumor forceps when small and attached to the inner wall of the uterine cavity by a pedicle. The removal may well be followed by a copper-mercury ionization of the stump. A cystic myoma will demand removal by celiotomy, as well as an infected fibroid—of the latter I have seen but one instance. Subperitoneal growths, attached to the uterus by pedicles and lying in the pelvo-abdominal cavity, may demand operative removal if large, as they do not respond well to the ray or to electrical treatment.

I do not include the few cases of sarcoma of the uterus that may be mistaken for fibroids in the list of those unsuited to radiation. Much stress has been placed by some writers on the occasional recognition of sarcoma in cases operated upon for fibroids as an argument against any other treatment. Unfortunately for this assumption, the operative removal of sarcoma of the uterus or ovary is followed usually by its recurrence. The ray promises a better result even when the diagnosis is made, as can at times be done by a consideration of the more rapid growth of the sarcomatous tumor as compared with a fibroid. Fibroids can rarely be noted as increasing in size in a period of a month, but a sarcoma may make a notable increase in size in that time.

Without going into full details of the X-ray treatment of fibroids of the uterus, it may be said that only rays of great penetration are effective, generated by a transformer that will yield at least a 9-inch spark supplying a broad focus Coolidge tube, though good results have been obtained from X-rays generated by a powerful static generator.

The rays should be thrown through the center of the tumor through three or four skin portals on the abdominal wall, to minimize the skin effect. The author has not employed massive doses, nor the treatment through more than one portal per day, fractional doses of 3 to 5 milliamperes being employed through six millimeters of aluminum for five minutes. The focal distance has been eight to twelve inches. The tube and patient should be so arranged that the rays will traverse the center of the tumor from each portal, the size of the portal of entry depending on the size of the growth. Except the portal, the whole of the patient's person should be protected by one thirty-second inch plate lead.

A series of such applications may be given each week for three weeks, consisting of a treatment through a single port of entry each day for three days—the right side, left side, and through the pelvic opening from the rear—the last with the patient lying face down, followed after an interval of a month by a repetition of the series, and have observed no unpleasant effects.

As stated above, if hemorrhage be a marked feature of the case, intrauterine copper-mercury ionization as described at page 292 with as large an olive as can be inserted, freshly coated with quicksilver, will assist materially in a quick control of the hemorrhagic tendency. It is applied with the anode within the uterus, of course, carrying a current of 40 to 80 milliamperes for six to eight minutes, repeated twice during the intermenstrual period or possibly only once, preferably ten days after the end of the period.

Functional Neuroses.—See Hysteria and Neurasthenia.

Gonorrhea.—This infection in woman usually attacks the anterior urethra and the cervical canal first. The electrical treatment may be copper-mercury ionization of the infected surface, applied in mild doses of 5 to 10 milliamperes on a copper sound that would fit the cavity and be sufficiently long to reach the whole tract. The duration should be ten minutes. The possibilities of electricity in gonorrhea are discussed more fully in the Chapter on Urology. Chronic gonorrheal infection of the Fallopian tubes is discussed under the heading of Salpingitis.

Hemorrhage, Uterine.—See Endometritis; also Menorrhagia.

Hyperemesis Gravidarum.—Stabile applications of moderate doses of both the direct and faradic currents have been advised, applied to the epigastrium from a moderate sized pad with the dispersing pad beneath the back.

Hypertrophy of the Uterus.—See Subinvolution of the Uterus.

Hypertrophy of the Cervix.—See Prolapse of the Uterus.

Hysteria and Neurasthenia.—Now that the reactions of the mind on the body are so much better understood than formerly, but a word need be said here as a warning against the misinterpretation of hysterical manifestations for local organic changes. In true hysteria, local treatment directed against illusory local diseases only intensifies the real disorder. In neurasthesia, on the contrary, the disorder of the nervous system may be due at times to local lesions, and treatment directed to the alleviation or cure of the local affection is indicated. The importance of a differential diagnosis between the two is manifest. For diagnosis and treatment see page 393.

Intestinal Stasis.—See Splanchnoptosis.

Menorrhagia and Metrorrhagia.—These conditions, when not due to the causes mentioned in the paragraphs on endometritis, are probably caused by glandular alterations of the endometrium or to hemophilia. The treatment is the same as that advised for endometritis.

Metritis.—See Endometritis.

Obesity.—Aside from conditions of hypothyroidia, relievable by administration of the thyroid extract, nothing acts as well in true obesity as natural, prolonged exercise and regulation of the diet. Much attention has been directed of late to the apparatus for muscle exercising of those who will not or cannot work devised by Professor Bergonie, of Bordeaux, France. This is an elaborate apparatus for directing properly regulated faradic currents to groups of muscles. The Morse Wave Generator produces a better current for this purpose, ampler and less painful contractions being obtainable from each flexor and extensor group by appropriate application of pads. The abdominal muscles should also receive full attention.

The Bergonie treatment of obesity has been described recently by Edward C. Titus, of New York, in a paper that will well repay reading.[1]

"This treatment should never cause fatigue. Most patients can tolerate an initial application of one-half hour, and this can be increased ten minutes each day until up to one hour in duration. Professor Bergonie has advocated that this full time can be borne by some patients twice daily, but I have found that one application per day is usually 'a genteel sufficiency.'

[1] *American Journal of Electrotherapeutics and Radiology,* March, 1920, p. 73.

"Since simultaneous stimulation of the entire musculature is to be obtained, the electrodes should be of ample size to cover the greatest area of the body surface. These electrodes are of two kinds, the stationary or semi-reclining chair, much like the ordinary steamer variety, but larger and more stoutly built.

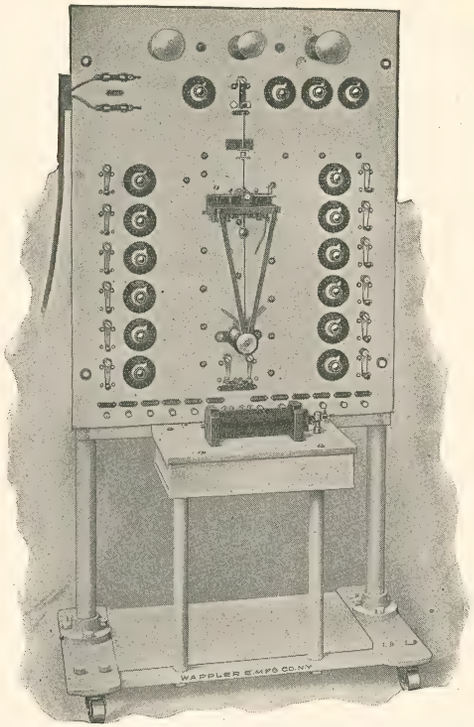


FIG. 146.—Bergonie Obesity Treatment Apparatus.

"Extending the full length of the back of the chair are two large metal electrodes, divided in the center—two on the seat for the buttocks and thighs and two on the adjustable extension for the legs. Attached to each of these electrodes is a cable connecting with the corresponding rheostat of the machine. The movable electrodes are six in number—two for the arms, two for the abdomen and two for the anterior surface of the thighs. They should be as large as possible and shaped to comfortably fit the contour of the parts.

"The chair is covered with a moderately thick bibulous towel wet with warm water, and the movable electrodes slipped in suitable sized covers (like a pillowslip) also wet. It is very necessary that the covering material of all electrodes should be of the same thickness, as the tension of the current from the machine to the patient being only 24 volts, the slightest difference in this detail will make the current irregular and quite unsatisfactory in its effects. The total area of surface covered by all the electrodes may amount to 10,000 cubic centimeters.

"The arm electrodes can be held in place by a crepe-velpeau bandage because of its elastic quality, while those on the abdomen and thighs are best secured by canvas bags filled with gravel or coarse sand. The total combined weight of these bags may vary from 50 to 100 pounds. They exercise considerable pressure which becomes an advantage in keeping the electrodes in good contact, and giving the muscles more work to do when they contract. This great weight is readily moved by the contracting muscles without the least fatigue or painful sensation. Were it not for the electric stimulation of the muscles, the above-mentioned great weight would be both difficult and painful to support.

"The subject removes all clothing but shoes and stockings. The body is covered with a suitable sized sheet, the opening coming to the back and pinned together at the nape of the neck only. This is separated as the patient sits down in the chair, the naked back, etc., coming in contact with the moistened towel, while the sheet affords ample covering for the anterior surfaces. The movable electrodes are adjusted next to the skin, and the sandbags put on outside the body covering.

"When this detail has been observed, it is my custom to begin the treatment by adjusting the current consecutively with the rheostat controlling the arm electrodes, the back, buttocks and thighs, and lastly the legs.

"The contractions should be only feeble at first, and after ten minutes or so gradually increased to a comfortable tolerance and eventually to vigorous muscular contractions.

"The usual course of treatment should extend over a period of from six to ten weeks. The applications should be daily for the first three or four weeks, then on alternate days for a similar duration. If further necessary, at longer intervals as the case may require.

"It will be noted that improvement is evident from the beginning of treatment. There will be a decrease in the gross dimensions out of proportion to the loss of bodily weight.

"This can be accounted for by the development of muscular structures and the absorption of the bulky adipose tissue.

"With some patients where rapid reduction and detoxication are urgently demanded, I employ for the first three days, in addition to the Bergonie treatment, a diet of weak tea and lemon water, small quantities of dry toast and fresh crisp lettuce ad libitum, together with liberal doses of saline laxative water morning and night.

"It is reasonable to expect—and this has been my experience—that in those cases where the patients conform to the requirements in regularity of treatment, diet and indicated exercises, a reduction averaging from half to one pound or more per day will be secured.

"It is pleasant to add that usually the improvement, as manifested by a sense of well-being, greater activity and more attractive proportions, will continue long after the treatment is terminated."

Polyps, Uterine.—See Fibroid Tumors.

Postpartum Hemorrhage.—In this at times desperate situation the patient's life should not be despaired of if a powerful faradic battery is at hand. An insulated olive electrode is thoroughly sterilized by boiling and inserted within the cavity, and with a large pad on the abdomen, the primary faradic current is turned on and maintained until the flaccid uterine muscle contracts and arrests the hemorrhage.

In the absence of this apparatus the patient's life may still be saved if there is an alternating current lamp socket and a lamp cord of sufficient length handy. The materials for this improvised apparatus are as follows: A double lamp cord long enough to reach from its plug in the socket to the patient; a piece of bare wire several feet long; a piece of rubber tubing from a douche bag, somewhat shorter than the wire; a china meat dish holding a half inch of plain water; and a little table salt nearby.

Wind one end of the wire over itself several times to make a bunch at this end of the size of a marble, pushing the wire through the rubber tube so that one end projects from one end of the tube and the other end projects several inches within the tube. This will form an excellent intrauterine electrode, all parts being insulated from the patient when inserted except the convoluted wire ball at the tip. Have the whole instrument boiled at once on the kitchen fire.

While the sterilization is being accomplished, separate the ends of wire from each other at one end of the cord (the current having been turned off or the plug removed from its socket),

and bare several inches of one and a foot of the other. The longer bared wire is coiled between the layers of a wet Turkish towel and placed on the patient's abdomen, thoroughly moistened with warm water. The shorter bared end is held by an assistant dipped in one end of the dish of water.

The sterilized intrauterine electrode is then inserted into the uterus; the current is turned on at the socket; and the end of the wire attached to the electrode inserted at the opposite end of the dish of water. A current will at once traverse the circuit of wires, water in the dish and the patient, that should be weak because of the wires being dipped a considerable distance apart (about a foot) in plain water. Now drop a small pinch of salt in the water, and increase the salt as the patient feels the current strengthen. For a still more powerful effect the wires may be brought closer together in the salt water, being careful not to permit them to touch. There is of course no electrolysis, but a most powerful contractile action may be produced.

Prolapse of the Uterus.—One of the most effective uses of electricity in gynecology is the relief, and at times the cure of all degrees of descent of the uterus except possibly complete procidentia, and even in the latter condition it is most useful before and after repair of the pelvic floor. Electrical treatment should, in my opinion, replace all such operations as ventro-suspension and fixation, particularly now that we have the rhythmic currents available for muscle stimulating treatments of proper power and duration.

It is my practice to discard pessaries at once in younger women and rely on this modality, accompanied by a few intrauterine applications of copper-mercury ions when the uterus is manifestly subinvoluted or hypertrophied, but this is not often required. The treatment gives comfort to the patient almost at once, and will shortly result in a progressive ascent of the organ if the pelvic floor is not too badly torn. In older women a pessary may be employed for a time in conjunction with the treatment.

In moderate degrees of descensus the active electrode may be vaginal, with the dispersing pad always abdominal, but in prolapse of the second and third degrees the active electrode is most effective within the uterus—a copper electrode as large as can readily be inserted, preferably coated with mercury. Current strengths should be as strong as the comfort of the patient allows.

What may appear to be a complete descent of the uterus may in fact be a descent of the cervix alone, by elongation of the cervix itself, the body having descended but little or not at all (Fig. 147). This can be ascertained by the bimanual examination, revealing the fundus high in the pelvis, and by the abnormal length of the cavity. The treatment outlined is equally applicable in this condition also, the internal electrode being passed into the cervical cavity alone and not beyond the internal os, with the addition of definite zinc-mercury cauterization of the

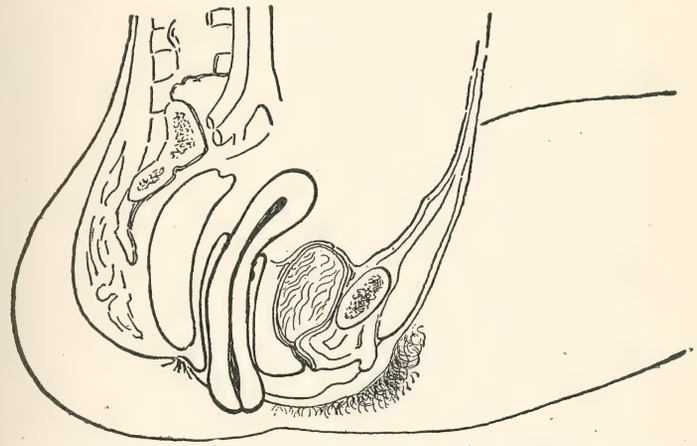


Fig. 147.—Sectional Diagram of Hypertrophy and Prolapse of the Infravaginal Cervix. The corpus uteri remains in position. (From "Conservative Gynecology and Electrotherapeutics," by G. Betton Massey, Philadelphia. F. A. Davis Company.)

cervical canal for its secondary contractile effect, the cauterization being done once a month between the periods with as much as 80 to 100 milliamperes for four minutes, followed by rhythmic wave currents. I have had excellent success with these procedures when the elongation was so great as to reveal the cervix between the labiae. If the elongated cervix does not retract within the vulva at each application it should be reposed.

Pruritus of the Vulva.—In this intractable affection medicinal ionizations of various remedies may be tried, or careful exposures to the X-ray. See also page 362.

Rectocele.—See Cystocele.

Retroflexion of the Uterus.—Retroflexion is of consequence only if produced by traumatism or associated with endometritis.

In the former case manual reposition with patient in the genu-pectoral position, followed by vagino-abdominal rhythmic currents, is indicated, and in the latter the treatment for endometritis. The flexion, as such, is probably incurable, but gives rise to no symptoms after attendant infection and hypertrophy have been removed by appropriate treatment.

Salpingitis.—Electricity may be used with advantage in both acute and chronic salpingitis, though the modalities are quite different. Both conditions are often due to the gonococcus, though at times tuberculosis has been shown to be the etiologic factor.

In acute or semiacute salpingitis diathermy is of value, and in the subacute stages the static wave current. *Neither should be used if conditions indicate abscess formation,* a rise of one degree of temperature contraindicating both electricity and diathermy.

In chronic salpingitis I have employed mercury ionization through the vaginal wall with good results in some cases, and thereby avoided the apparent necessity for removal of the organ. The copper ball electrode is heavily coated with quicksilver before each application, which should be stabile, or without waves, with the electrode pressed gently against the enlarged tube and the pad above it. Currents of 60 to 80 milliamperes may be used for ten minutes twice a week, with the high-vacuum tube or X-ray applications between the ionizations. The vaginal ionization will necessarily create an erosion at the site of the application, but this heals readily. It is believed that the ions reach both the tube and the ovary after several applications, as they tend to lessen menstruation temporarily. The most obstinate cases are those due to the gonococcus.

There are some cases of old pus tubes without present temperature reactions, associated with chronic endometritis, in which cautious intrauterine applications appear to make the tubes patulous as a secondary result. The greatest gentleness is required in the insertion of the electrode and small milliamperages, repeated but twice a month.

Scanty Menstruation.—See Amenorrhea.

Sexual Frigidity.—See Anaphrodisia.

Splanchnoptosis.—Enteroptosis. Whether rhythmic wave currents can be of service in the sagging of nonmuscular organs would depend on their power to alter the circulation of these organs by direct action or by action on the neurons supplying

them. Improvement in the clinical condition of these cases under the treatment implies that they do have an effect in one way or another.

But in ptoses of the muscular organs due to atony, the stomach, small intestine and large intestine, the value of powerful waves sent through the abdominal walls in sufficient force to locally stimulate the smooth muscle fibers affected is self evident. With kaolin pads on the abdomen and beneath the back 150 to 200 milliamperes may be sent through the parts painlessly in sinusoidal waves of 28 to 30 per minute, furnishing enough potential to reach the sagging tissue with the proper density. With this technic, or with powerful Morse currents, it is unnecessary to attempt the local application of electricity within the stomach, for an even greater density can reach the organ through the abdominal wall in this more agreeable manner.[1]

Sterility.—The electrical treatment of sterility is most successful when the sterility is due to some abnormal condition of the mucous membrane of the uterus which itself is curable, such as superinvolution, chronic endometritis or glandular endometritis. If these conditions are not present the cathode of the direct current may be used intrauterine, 20 milliamperes once a week, followed by a vagino-abdominal sinusoidal wave application twice weekly. A very small "pin hole" os may be gradually enlarged by the use of progressively larger sizes of electrode.

Barton Cooke Hirst, of the University of Pennsylvania, has written interestingly on these subjects as follows, under the title of "The Development of Infantile Uteri by Negative Galvanism."[2]

"Women who are sterile in consequence of ill development of the uterus are applying to specialists in increasing numbers. The reason for this I think is the increasing stress and strain of modern life, possibly experienced by the mothers of the present generation before their birth; possibly due to the strain of modern life on the young, growing girl. I find this condition more frequently among members of the working classes and I think it is particularly frequent among the large number of

[1] An interesting discussion of the physiologic conditions that may be influenced by this treatment to the abdomen is contained in a paper by G. K. Dickinson on "The Myenteric Nerve Net," in the *Journal of the Amercan Medical Association,* for February 14, 1920, Vol. 74, No. 7, p. 442.

[2] *American Journal of Electrotherapeutics and Radiology,* January, 1920, Vol. XXXVIII, p. 4.

Jewish immigrants who have recently come to this country from Russia.

"Whatever the reason the fact is, I believe, indisputable.

"An interesting question which presents itself to all specialists dealing with such cases is, what means have we at our command for correcting this cause of sterility? After a number of years' experience with large numbers of these cases, I have standardized my practice as follows: First and foremost I find it necessary to resort to a dilatation of the cervical canal, for a marked stenosis there is one of the symptoms of the condition; but this alone will rarely suffice. Following the dilatation which I can secure most efficiently and safely with the metranoicter I prescribe a course of treatment over some three months or more, of hypodermic injections of corpus luteum extract and the extract of the anterior lobe of the pituitary gland taken by the mouth. By this treatment alone I have observed a number of conceptions after some years of sterility. But there remains a considerable proportion of cases in which no result is obtained. The uterus still presents its original small size with the other symptoms of infantilismus and there is the same scanty and infrequent menstruation with the history of late establishment of that function.

"The only treatment which is available in such cases, as far as I can see, is electrical stimulation of the uterine muscles; a method which would naturally suggest itself in the case of any ill developed or atrophied muscle. By this treatment in the course of the last fifteen years I have secured results which I do not think could have been obtained in any other way. To present accurate statistics of all my cases would require a search through my private records and the records of my hospital services which I have not had time to make, but I can give illustrative cases showing I think what may be expected from this treatment, and if such results are only secured in an occasional case, it makes the treatment well worth the trial.

"Case I.—A young woman came under my observation with ectopic gestation. She presented the characteristic history of late institution of menstruation which then occurred scantily and infrequently. The cause of the ectopic gestation in that case I believed to be the ill development of the tubes and the narrowness of the canals. After my operation for ectopic gestation this woman remained sterile thirteen years. She then applied to me for treatment of her sterility. I found all the clinical symptoms and the physical signs of infantile uterus. After a dilatation of the cervical canal which had no result this woman was subjected to three months treatment with electrical

stimulation. Shortly after the completion of the treatment she conceived and bore a child at term.

"Case II.—A woman married one year gave me the history that since marriage she had not menstruated at all. She confided to me the statement that some time before her marriage she had given birth to an illegitimate child of which her husband knew nothing. On examination I found the evidences of marked superinvolution. I applied electrical stimulation to this woman's uterus only four times. After the fourth treatment she menstruated for the first time in a year; her menstruation was profuse and lasted ten days. She never menstruated again as she became pregnant directly after the cessation of this first period and gave birth to a child at term. Her subsequent history I do not know.

"Case III.—A lady among my patients developed superinvolution after each childbirth. This was accompanied by headache of the severest character; her menstruation became more and more scanty and *pari passu* with the decrease of the flow her headache steadily increased. I subjected her to two courses of electrical stimulation; in consequence of each, her menstruation became normal and she twice conceived. Following the second birth, although the original symptoms returned more aggravated than before, the patient refused further treatment, for, as she stated, she would rather submit to her frightful headaches than to become pregnant again, as she felt certain that the result of my treatment while relieving her of her symptoms would again result in impregnation; whereas without the treatment the superinvolution which she always developed after childbirth gave her immunity against conception.

"Case IV was a woman 25 years of age who gave a history of four years of marriage without conception. She menstruated for the first time at 17 and following that usually had intervals between her periods of three to five months. I found the ordinary physical signs of infantile development; subjected her to dilatation of the cervical canal, followed that by corpus luteum injections and the extract of the anterior lobe of the pituitary gland, but without success. A year later this patient was given electrical stimulation of the uterus for a period of nearly three months. I lost sight of her for some time but she returned to me more than a year later stating that she had given birth to a living child. Since then she has been delivered again. Her periods are now regular and normal and she is capable of repeated conception.

"I could multiply these illustrations by a considerable number from my private records and the records of my two hospital services, the University Hospital and the Howard Hospital, but I think these cases demonstrate sufficiently clearly what it is possible to accomplish by electrical stimulation of an ill developed or atrophied uterus.

"The method of treatment which I have finally adopted during the last twelve or fifteen years is as follows:

"A copper electrode is inserted in the uterus with the necessary aseptic precautions. A large sponge electrode is placed over the abdomen; the patient is then given galvanism with the negative pole in the uterus, nine to twelve milliamperes. This is followed by rapid and slow faradism; finally by the sinusoidal current, the treatment continuing for twenty minutes and being applied every other day, intermitted in case the menstruation occurs but otherwise continued for about three months. I have never seen any result except once secured by less than six weeks' treatment, but I am not satisfied that the patient gets a full result from the treatment under three months. So far I have seen no infection of the endometrium or of the appendages follow this treatment, but naturally the greatest care in aseptic technique is necessary.

"In case the cervical canal is too narrow to admit one of the copper tipped electrodes made for intrauterine use, I employ a narrow flexible platinum electrode which is practically indestructible. I have had one in constant use now for about ten years without any deterioration. Another result of this treatment is the permanent enlargement of the cervical canal by electrolysis so that the dysmenorrhoea which is an almost constant accompaniment of the lack of physical development is usually permanently cured. Another curious result which is secured incidentally is the cure of chronic constipation. After a number of experiences of this kind I feel that the best treatment for the permanent cure of constipation in women, if exaggerated and resisting ordinary methods of treatment, is the application of electrical stimulation to the abdomen by means of a large abdominal sponge pad, the other pole being placed either in the uterus, the rectum, or simply in the vagina. In the latter case a larger bulb electrode being employed.

"In view of the demonstrated possibilities of this treatment it seems to me strange that it should be ignored by most gynecologists. There was a prejudice excited among specialists in the treatment of diseases of women by the immoderate claims made in behalf of electrotherapeutics for the female pelvic organs when this method of treatment first came into vogue, so that there was a disposition to regard it with some degree

of skepticism not to say ridicule. While it is true that the immoderate claims which were made for electricity in many of the affections peculiar to women were unjustified in fact, there is no doubt at all that for this one condition it remains the most available last resort and can be expected to secure results when other methods of treatment have failed.

"This is what one might logically expect. There would be no hesitancy in applying electrical stimulation to ill developed or wasted muscles in any other part of the body.

"I hope to see in the future a wider application of this method at the hands of many specialists so that a collective experience will demonstrate to the profession what my individual experience has taught me."

An important improvement in the electric treatment of the infantile uterus is pointed out by Herbert F. Pitcher, of Haverhill, Massachusetts, in a paper before the American Electrotherapeutic Association in 1918,[1] in which he advises that the sinusoidal rhythmic current be employed, with the electrode carried back into the uterine cavity after the dilating, cathodic application has been made to the cervix. He has seen the uterus double in width after two or three months' treatment.

Subinvolution of the Uterus.—It is probable that every puerperal woman would be the better for a course of nongalvanic rhythmic currents after the cessation of the lochia. Delayed involution is greatly speeded up by this modality. It is not necessary to insert the active electrode within the uterus, as the ball electrode in the posterior fornix is usually effective.

Superinvolution of the Uterus.—See Sterility.

[1] *American Journal of Electrotherapeutics and Radiology,* December, 1918, p. 307.

CHAPTER XIV

ELECTRICITY IN DISORDERS OF THE ABDOMINAL ORGANS

Mode of Action—Ascites—Atony of Stomach—Autotoxemia—Colitis—Constipation—Dilatation of the Stomach—Enteroptosis—Gastralgia—High Blood Pressure—Intestinal Obstruction.

The rational application of electric force to disorders of the abdominal organs is based on three clearly defined physiologic actions of this force: contraction of muscle fibers, both striated and unstriated, by rhythmic wave currents; induced active hyperemia in internal organs from diathermy; and wave excitation of the neurons of the sympathetic nervous system. By keeping these methods of action clearly before us we will not be led to form exaggerated expectations of its value, on the one hand, or the giving of ineffective treatment that is too weak though well advised, on the other.

The action of electric waves on muscular tissue of both kinds has been an established fact for two generations, yet it has been one of the most neglected agents for the restoration of muscular tone in the abdominal wall and in the hollow organs. It is not merely that this agent has been totally neglected by surgeons in favor of unscientific attempts at straightening, removal of ptoses of freely floating organs by artificial fixation, or by shortening, when restoration of muscular tone should be the aim; but electrotherapeutists themselves have used ineffective currents for this deep penetration by the employment of too small electrodes, and failure to use rhythmic waves. Large kaolin electrodes are essential, or others with equally good skin contact, and the recent perfection of rhythmic wave generators (page 72), has greatly enhanced these possibilities.

The production of hyperemia by diathermy (Chapter VIII) in the spleen, pancreas, liver and kidneys is a well established possibility, and opens the way to an effective means for combating congestions and minor chronic affections of these organs.

Diathermy is also valuable in combating pain from spasms of portions of the intestines.

Rhythmic wave excitation of the sympathetic neurons controlling the functions of these organs, or of their parenchymal tissues, has not been the subject of recent research, so far as the author is aware. That this excitation is possible with adequate current penetration is, nevertheless, very probable when we recall the experiments of Brown-Sequard on the sympathetic nerve in the neck of a cat, and its result in dilating the blood vessels of that side of the neck. This experiment was, of course, made by the direct application of the current to the cut nerve, but the same conditions exist if the percutaneous current wave be so strong at the skin that its concentration at the nerve equals the strength of the direct application to the nerve.

The solar plexus, in particular, with no large trunks of spinal nerves between it and the integument, is quite accessible to a powerful current wave transmitted painlessly through the abdominal wall from a 6 by 6 inch pad on the epigastrium to a larger pad beneath the back. Such rhythmic stimulation of this plexus with current of 50 to 150 milliamperes has seemed of great value in those forms of neurasthenia thought to be of abdominal origin; while similar rhythmic waves administered below the navel are at times followed by a freer flow of urine. A possible explanation is direct neuronic stimulation.

Appendicitis.—See Colitis.

Ascites.—As this condition is a mere symptom of organic disease in one or more secretory or excretory organs, no radical relief is possible without removal of the cause. Yet, its symptomatic relief has followed rhythmic wave treatment in several cases, and even faradic treatment in former years, in the author's experience, with improvement in the general health. The later method of treatment was with large abdominodorsal kaolin pads and slow waves, the treatment being prolonged to a half hour daily or triweekly.

In a case of ascites with general anasarca recently referred by Dr. Hedges, of Plainfield, New Jersey, the patient's appearance greatly improved as the features of the face and the lines of the upper chest and arms emerged from their bloated condition. The greatest circumference of the abdomen at the beginning of the treatment was 49½ inches. This was reduced to 42 inches after several months' treatment. The patient's condition remained improved four years later. The etiology remained uncertain.

Atony of the Stomach.—Atonic Dyspepsia. Various forms of intragastric electrodes have been devised, notably the fenestrated rubber olive electrode of Einhorn, which is attached to a flexible insulated cord and swallowed, with sufficient water to dilate the viscus, but these attempts at polar treatment with mild currents within the stomach do not justify themselves for the discomfort of the application. It is impossible to thus localize the polar action of the galvanic current to an ulcer, while contraction of the muscular layer of the organ may be produced equally well or better by far stronger rhythmic wave currents passed through it from the skin surface.

The percutaneous application of diathermy, with epigastrodorsal electrodes of suitable size, followed by similar sized kaolin pads through which the galvanic current of comfortable strength is applied (cathode to epigastrium), has seemed of great benefit in obscure cases of dyspepsia with local discomfort. This procedure is valuable as a diagnostic agency in excluding carcinoma of the stomach. In two cases recently seen, one of which presented an induration that strongly suggested carcinoma when the falling weight was also considered, the use of this treatment was followed by such improvement as to seem to exclude malignancy. Both cases were in the persons of physicians, and had received able study from others without a conclusive diagnosis having been made. The induction of active hyperemia would seem to have been the mode of relief.

Autotoxemia.—See Colitis, Constipation and Enteroptosis.

Colitis.—This distressing chronic condition, believed by the author to be an infection primarily rather than a neurosis, is greatly benefited by the stabile application of the galvanic current over the painful spot, as described in the paragraph on Atony of the Stomach, provided the infection is adequately combated by doses of 30 to 60 grains of betanaphtholate of bismuth suspended in some menstruum, both being given between meals daily. I know of no more valuable treatment of this condition, quicker results by far being obtained than by any method of intracolonic medication by lavage, or surgical intervention. Should enteroptosis be associated with the infection, as is so often the case, rhythmic wave currents should also be pushed.

Constipation.—Electric force offers two physiologic modes of restoring intestinal functions to normal: stimulation of peristalsis by passing an effective series of wave currents through the muscular layers of the intestine from large electrodes on the skin

surface, and stimulation of gland function by the galvanic sinusodial waves similarly applied. In both cases large pads and powerful currents are best.

A number of electrotherapeutists advise the placing of one electrode within the rectum, by the use of a hollow, insulated tube through which normal salt solution is injected to create an enlarged pole. This is notably advised by Dr. Curtis Webb, of London. With a dispersing pad on the abdomen, rhythmic waves may be applied in this way. This is a valuable resort in difficult cases, but the percutaneous method, with large abdominodorsal pads, will allow of far more powerful currents than is possible in the rectum without excoriation, as much as 150 milliamperes of the galvanic sinusoidal waves or the full strength of the surging alternating wave. The application should last thirty minutes and may be repeated daily. Immediate evacuation has followed this treatment. The waves should be from 11 to 25 per minute.

The author frequently conjoins an ancient remedy with this treatment when there is no colitis present. This remedy, mentioned by Aetius, is the swallowing of from one to two teaspoonfuls of whole white mustard seed (*sinapis alba*), immediately after dinner and without chewing them. It is well known that the oil of mustard is only developed after the crushed seeds are admixed with water. By swallowing them whole, immediately after the most copious meal, this acrid stimulant of muscle and gland is formed in the middle and lower intestine in minute doses after the slow maceration of the woody envelopes of the seeds, and may even be detected at the anal outlet.

Dilatation of the Stomach.—The indication is for externally applied rhythmic wave currents, or their association with gastric lavage as an intragastric application.

Dyspepsia.—See Atony of the Stomach.

Enteroptosis.—The physiologic response of the smooth muscle fibers of the intestines is referred to in page 74. With such a convenient means of stimulating these muscles by powerful rhythmic waves sent through the abdominal wall from perfectly conforming kaolin electrode pads (abdominodorsal application), it is strange that operative intervention, with its dangers of angulation and fixation of the tube, should ever be thought of. Such intervention is akin to taking tucks in an old suspender when we really have a means of renewing the elasticity of its contained rubber. It is far worse in possible consequences

than this homely illustration, with its possible consequential obstruction.

In actual practice, much patience, powerful doses of the waves administered from large pads in half hour applications, with such perfect contact at the skin conduction points as to minimize skin irritation, and continuance of the treatment for six months or a year, is essential to success. But the evident improvement in the subjective symptoms is an early encouragement to patient and physician alike, and the progress may be verified by radiographs at intervals of six months.

Gastralgia, Chronic.—See Atony of the Stomach. The indications for the relief of pain are best met with diathermy, the static wave current, or percutaneous galvanic applications to the epigastrium.

High Blood Pressure.—Directions for the application of autocondensation to the condition indicated by high blood pressure will be found in page 111. The reduction of the excessive pressure, as measured immediately after the application, is quite uniform, and there is usually a progressive slight reduction found in the pretreatment measurements if continued triweekly or biweekly. A slight amount of albuminuria may even be removed after a number of such treatments, with much relief of the subjective symptoms of nervous tension.

It would seem, therefore, that autocondensation is more than a temporary symptomatic relief in this condition. Its mode of action is supposed to be the dilation of the internal vascular system by the heat flowing down from the shoulders, this circuit being favored by the hands and arms being either removed from the patient's side or insulated therefrom by a folded towel while the patient is in the recumbent position.

Hyperemia of the Kidney.—See High Blood Pressure.

Hyperesthesia of the Stomach.—Hyperemesis Gravidarum. See page 307.

Intestinal Obstruction.—In a special article by Larat, of Paris, in the "International System of Electrotherapeutics," page 37, a number of cases are related in which intestinal obstruction was relieved either by external faradic applications (the best current for the purpose then available), or by intrarectal lavage applications of the same current. It would seem that this method, with surging rhythmic waves, should receive trial in a given case before laparotomy if the condition of the patient permits.

CHAPTER XV

ELECTRICITY IN UROLOGY AND PROCTOLOGY

Mode of Action—Apparatus Needed—Arthritis—Carcinoma of Bladder — Chancre — Chancroid—Condylomas—Cowperitis—Cystitis—Epydidymitis—Fistula in Ano—Fissure in Ano—Folliculitis—Gonorrhea—Hemorrhoids—Hypertrophy of Prostate—Impotence—Papilloma of the Bladder—Spermatocystic Vesiculitis—Stricture of Urethra.

Electricity, in some of its general modes of power transformation within the body, has almost as many useful therapeutic applications in the male pelvis as in the female pelvis, with a history nearly as long, though confined to several conditions only. There are indications that present day urologists are awakening to its broader possibilities as an adjuvant to other appropriate remedies, and also as the principal reliance in certain affections.

The following notes are offered as suggestions to the urologist from one familiar with electrical technic alone in this specialty, and represent either personal experiences extending over many years, or a judgment of others' work based on that experience. It is hoped that they will lay a foundation of accurate electrical technic that may be broadened in the hands of those specializing in urology.

Mode of Action of Electric Power in Urologic Affections in the Male and in Proctology.—The germicidal action of ionization as an abortive and curative treatment of acute gonorrhea should be put to adequate test in skilled hands in America, in view of the reports on this method from abroad.

In chronic conditions, besides germicidal effects from ionization, we may invoke by electrical methods the remedial action of hyperemia and other effects of diathermy near the surface and in the deepest structures; the lubricating and relaxing action of the cathode of the direct or galvanic current developing alkaline and soapy ions at the site of strictures; coagulant ions within blood tumors, as in hemorrhoids; nerve and muscle stimulation

by rhythmic wave currents in relaxed neuromuscular structures; and destructive effects in neoplasms—all in accurate dosage and under perfect control.

Apparatus Needed by the Urologist and Proctologist.—Direct current apparatus will form an important item in the equipment for Urology and Proctology, the apparatus differing from others only in being supplied with a meter having a scale in single milliamperes up from 0 to 10 or 20 as well as the ordinary scale reading from 0 to 400; or, if major direct current coagulation is to be employed, a scale from 0 to 2500 milliamperes.

The other apparatus includes a high frequency transformer capable of desiccation and coagulation as well as autocondensation; rhythmic current apparatus; and the best static machine if the static wave current is to be employed. In other words, a complete outfit is required if the varied needs of urology and proctology are to be filled. The active electrodes will be described as their uses are indicated.

The electrical treatment alone is referred to in the following conditions. It is not assumed that the urologist will neglect other appropriate treatment.

Arthritis, Chronic, Gonorrheal.—Thermotherapy is a valuable means of arousing tissue resistance in the chronic stage of this metastasis. It may be applied in the form of phototherapy from a 100 watt lamp with parabolic reflector for prolonged periods, or we may use diathermy with 3 by 4 inch plates on each side of the affected part and a current producing comfortable heat.

Carcinoma of the Bladder.—Electrocoagulation methods (page 282) applied through a suprapubic incision into the bladder, the site of disease being illuminated by the glass-enclosed miniature lamp, is the most promising mode of treatment.

Chancre.—A description of a proposed abortive treatment of syphilis, if applied within five days of the initial lesion, may be found on page 49.

Chancroid.—Zinc-mercury ionization is indicated in this local infection, boldly applied, but needle electrodes would probably not be needed, the anode being a bulb or plate of thin zinc, the latter cut to the shape of the wound and amalgamated with quicksilver. Some 2 per cent. solution of zinc sulphate may be poured into the cavity for better distribution of the ions. With dispersing cathode pad on the back a current of about 10 milliamperes per square inch of anode surface is turned on and maintained for half an hour, being repeated a week later. Abscessed glands in the groin can be healed quickly by the same technic and weaker currents.

Condylomas of syphilitic or other origin are most conveniently destroyed by the desiccation method with the Oudin current, the wire point being from one eighth to one quarter inch from each condyloma. They may also be destroyed by zinc ionization with a fine zinc needle inserted into the tip of each condyloma and a dispersing pad elsewhere on the body.

Cowperitis.—Victor Pedersen has the following to say on this condition.

"Electrotherapy is forbidden by acute inflammation but acceptable in declining and chronic periods either with or without occlusion. It stimulates the evacuation of pus, the destruction of infection and the restoration of the infiltration. When infection has nearly or fully disappeared, galvanic cataphoresis (ionization) with a small electrode wound with cotton soaked in weak solutions of zinc chlorid or copper sulphate and attached to the positive pole, or in one tenth to one fourth strength of the tincture of iodine and connected with the negative pole, may be used in 3 to 5 milliamperes of current for five to ten minutes every three to five days. There should be no reaction and only benefit. If infection is present then the x-ray vacuum glass electrode attached to the negative pole of a standard high speed multiple plate static machine is used, with intensity of current of a spark gap one half to one and a half inches for five or ten minutes every three to five days, likewise always with benefit and without excitation. Its strong actinic and germicidal effects are thus localized upon the glands. Experimentally the actinic effects penetrate to a depth of from 2 to 6 millimeters, depending on the intensity of the current employed." [1]

Cystitis.—In acute cystitis the application of phototherapy to the hypogastric region of the patient while in his bed at home is valuable, in conjunction with other appropriate measures, and can be readily carried out if there is a lamp socket supplying the electric current convenient and a lamp cord and hand lamp with reflector of some kind to be had. An ordinary 50 watt mazda lamp will give enough heat for continuous applications of an hour or more, with the light either thrown directly on the skin or through one thickness of muslin. If the lamp is enclosed in

[1] "Urology," by Victor Cox Pedersen, Lea & Febiger, Philadelphia, 1919, p. 113.

a pasteboard box such as those in which shoes are sold, to the bottom of which the lamp is tied, the whole may be placed directly on the skin with the open side next the skin, the projecting edges of the box preventing the lamp or metal reflector from coming into contact with the skin. The whole should be covered with bed coverings.

In chronic gonorrheal cystitis the filtered, deep penetration X-ray from a tube backing up a 9 inch spark, with 5 milliamperes of current passed through five millimeters of aluminum and one thickness of sole leather, has been recommended as a sterilizing agent.

Epididymitis.—In acute epididymitis the same measures for prolonged electric light applications are indicated as described above for acute cystitis.

In the chronic condition the vacuum tube or non-vacuum tube thermopenetration is indicated, applied to affected parts and the vas deferens, daily for fifteen or twenty minutes, or mild diathermy, not over 300 milliamperes. (Pedersen.)

Fistula in Ano.—(See also page 145.) The ionization treatment of fistulas in the perineal region has been employed by the author in a number of cases with uniform success, in both blind fistulas and in those that have both an external opening in the skin and another in the rectal wall inside the anus. Complete healing resulted in both classes of cases, though those with an internal opening usually require more applications. In these cases with internal openings the closure of the inner opening is to be favored by first ionizing the opening at the initial treatment by passing the electrode slightly through into the rectum, as ascertained by the gloved finger passed through the anus, the finger or a rubber spatula or rubber finger cot being kept in place during the application to protect the opposite wall of the rectum. Thereafter this inner opening is to be allowed to close and the electrode passed successively into the various pockets which usually exist in these sinuses, particularly if they be of tubercular origin.

Copper ions from copper wire electrodes have been employed by others in the treatment of perineal fistulas but the author's work has been entirely with the zinc and mercury ions, diffused from a zinc probe amalgamated with quicksilver. The technic is that of unipolar zinc-mercury ionization described at page 145. More current power will be borne in these fistulas than in the tubercular sinuses of the neck, permitting of the pushing

of the treatment to an earlier termination. If the cavity be distinctly multilocular a record should be kept of the direction in which the electrode is passed at each application and a different pocket be sought at each treatment.

The advantages of the ionization treatment of fistula in ano are that the patient may be ambulant during the treatment, and that division of the sphincter is not needed.

Fissure in Ano.—This very painful condition is readily cured by zinc-mercury ionization from a blunt anode applied directly to the fissure with a current of 5 to 10 milliamperes for ten minutes, the part being anesthetized ten minutes previously by dusting a little crystallized or powdered cocain or synthetic substitute on the fissure. After treatment consists in the use of diluted zinc ointment. The treatment should be repeated in about three weeks if the first application is not followed by a tendency to complete healing.

Folliculitis.—These chronic follicular inflammations are readily cured by single applications of 1 to 2 milliamperes of zinc ionization from the tip of a fine zinc needle inserted into the follicle, or by desiccation with the Oudin current.

Gleet.—See Stricture of the Urethra.

Gonorrhea.—Russ, of London, has introduced a new treatment of gonorrhea of such apparent importance that a full account of it is here given, taken from his recent work on the subject.

"The treatment is founded upon experimental studies of the behavior of bacteria immersed in fluids which are traversed by a constant electric current, and the observations apply to the gonococcus as well as to other bacteria.

"If a bacterial culture be made, and the growth upon agar is thoroughly shaken up in a common salt solution, so as to separate any microbial clumps, we have a milky fluid in which the organisms remain in suspension, and only after many hours do they gravitate and form a sediment.

"To observe the effects, such a suspension is placed in a glass U tube furnished with electrodes, and a small constant current is passed. After a while the uniformly milky fluid will undergo a change, a zone of increasing density will form at the anode, and this density is due to the arrival of the bacteria, which are migrating from other parts of the tube.

"If the system be left, the process continues until all the organisms have accumulated at the anode, leaving the rest of the fluid clear.

"Another fact of importance is the death of the organisms, which takes place soon after turning on the current.

"We are therefore in possession of a new kind of force in dealing with bacteria, and in recent years the author has been making clinical application of these experimental facts in the treatment of suppuration, of which gonorrhea forms an example.

"If we immerse the diseased area in a salt solution through which a current is then passed, we are bringing into play the forces visible in the experimental observations.

"If this be successful, the bacteria should be drawn from the suppurating area, and the lethal effect is also at work.

"Manifestly, both of these agencies constitute a new kind of treatment when applied to gonorrheal suppuration, and the method evolved may now be described for the treatment of an acute case of gonorrhea in a man.

"The patient is required to retain urine for a few hours, and the rate of discharge is visible on a disc of cotton-wool retained within the prepuce. A Gram-stained smear is made of the discharge at the outset of the treatment. The patient is directed to pass about half of the urine he is retaining, and keep the rest back.

"This preliminary urination washes the urethra from behind, and is the only lavage employed. He then reclines on the couch, and a platinized catheter is lubricated and passed gently down to the compressor urethrae. This catheter, which is quite smooth, has numerous perforations, and it is furnished with a stylet of platinum wire and a rubber collar which just enters the meatus. I also use rubber perforated catheters. A lint-covered pad lined by a flexible metallic core is wrung out of warm saline and applied to the perineum, scrotum, and root of the penis. A 2 per cent. solution of sodium iodid (containing $\frac{1}{10}$ per cent. iodin dissolved) is then gently injected into the catheter. The rubber collar prevents its flowing away between the instrument and the urethra. The pad is connected to the cathode, and the stylet (within the catheter) to the anode of the battery. A current of 1 to 3 milliamperes is passed for ten minutes, and then reversed for another ten minutes, and the catheter is kept full of the solution from time to time by means of a syringe.

"At the end of each treatment the catheter is withdrawn, and its contents are noted by immersing the instrument in a glass of water.

"The numerous masses projecting from the perforations are composed of muco-pus; and microscopic examination shows them to be literally swarming with killed gonococci—a harvest of morbid matter, so to speak.

"One finds that leucocytes (pus cells) are also conveyed to the anode—i.e., the stylet within the instrument—and in this way the crypts and the glands and their ducts are emptied of their contents.

"Part of the harvest is also to be noted in the urine voided after the treatment, and this represents more masses of muco-pus and gonococci which have been drawn into the urethral channel or have clung to the urethra during withdrawal of the instrument.

"This harvest diminishes with successive treatments, and this happens although the time of electric treatment and the current strength remain the same, the obvious inference being a diminished urethral content of gonococci and pus cells. In the final stages no visible harvest occurs, and when this is the case no more urethral discharge will occur.

"To summarize the effects of the electrolysis treatment in gonorrhea, we find we are—

"(1) Emptying the urethra and its recesses of the gonococci. (2) The organisms are being killed in situ. (3) The organ is being congested with blood, and the antibodies are in this way given full play at the centers of the mischief.

"It must not be forgotten that these effects are brought about without irritation of the parts by antiseptics, and avoidance of lavage prevents the loss of valuable antibodies.

"The cases I have treated, whether in private or at the Lock Hospital, have done so well that, personally, I should not think of treating acute gonorrhea by any other method. So far, I have treated over seventy cases of gonorrhea by electrolysis, and I believe the advantages to be: (1) The limitation of the inflammation to the anterior urethra. (2) The absence or rarity of arthritis, ophthalmia, and epididymitis. (3) Comparative rapidity of cure. (4) A painless procedure.

"The electrolysis is administered every day in an acute case until the discharge is slight, at which stage the patient may take santal oil and receive electrolysis every other day. The discharge will next cease entirely, and after a few more electric treatments the pus threads and epithelial flakes will disappear from the urine and recovery be established." [1]

In chronic gonorrhea Russ makes a similar application to the deep urethra twice or three times a week, employing either a rubber or platinized silver catheter with perforations only for a distance of 2½ inches from the deep end. Continuing the quotation from his book:

[1] "A New Treatment for Gonorrhea," by Charles Russ, Physician in Charge of the Electrotherapeutic Department, the Male Lock Hospital, London, H. K. Lewis & Co., Ltd., London, 1916.

"Such a catheter is passed into the bladder, and as soon as the urine flows the instrument is gently withdrawn until the flow ceases. At this point one knows the perforations lie within the diseased area.

"By means of a funnel or a syringe the sodium iodid solution is made to fill the instrument, and a wire stylet is passed only 3 or 4 inches down the catheter, dipping into the injected liquid when using the rubber instrument. When the platinized catheter is used, the stylet should traverse its whole length, and it should be screened by a fine rubber tube which reaches only to the upper end of the perforations. In this way we prevent the current taking a shorter route from the pad through the scrotum and penis.

"The stylet is connected with the anode and the pad with the cathode of the battery.

"Since the deep urethra is sensitive, only half a milliampere of current is turned on for the first occasion. This current passes from the pad through the buttocks and perineum, and converges through the floor and sides of the deep urethra to the perforations of its contained catheter. The current ascends the fluid in the catheter, and completes the circuit by meeting the submerged stylet.

"By the injected fluid we have provided a layer of iodid solution between the perforated area and the deep urethra, and in this way the electrolysis [ionization] is focussed upon the diseased area.

"At the end of twenty minutes the current is stopped and the catheter is drawn out and placed in a glass of water. One then sees masses of muco-pus, strings of mucus, and numerous flakes —in fact, the harvest, but on a smaller scale than in an acute case after anterior urethral treatment. The rest of the urine is then voided, and the débris observed, and it may be stained and examined by the microscope.

"In such a case, after about twelve such treatments the patient will usually report a cessation or diminution of the discharge. In the latter cases, I have obtained a cure after following such treatment as long as three months—i.e., about twenty-four administrations."

Dr. Russ also employs a sodium iodid solution to which a little more iodin has been added, enough to color it slightly. His unusual practice of reversing the current is explained by him as desirable in order to keep the fluid next the urethral mucosa neutral and not alkaline, or at least neutral at the end of the application by employing an equal current for an equal

time in both directions. He believes that better results were obtained in cases in which the current was reversed.

This method deserves careful trial by urologists, following the technic of its introducer. To an electrical worker the perforated rubber catheter with conducting stylet would seem ideal, the metal one being liable to set up irregular current action.

Other methods worthy of trial would be gentle ionizations without reversal, in which Russ' perforated rubber catheter would be used with one per cent. solutions of copper sulphate or zinc sulphate, stylets of a copper wire or of zinc wire of the length given by Russ being used with the appropriate ions.

Hemorrhoids.—The electrical treatment of hemorrhoids has passed through several phases in the author's practice. A mild degree of varicosity of the hemorrhoidal veins can be relieved, as urged by some of the older electrotherapeutic writers, by the application of what we now know as rhythmic currents (Chapter VII) with a metal olive in the rectum and a dispersing pad on the abdomen. This may prove effective if associated with an old-fashioned medicinal remedy. I refer to the administration of a teaspoonful of yellow mustard seed, swallowed without chewing the seeds, immediately after dinner. As it is well known that the active principle of mustard, the kind usually sold at grocery stores and preferably bought there by patients, the sinalbin does not become a stimulant until it unites with water, the unbroken hulls of the seeds permit this action only with great slowness when mixed with the intestinal contents, producing a very gradual action on the intestinal mucosa, and probably acting also on the portal circulation, for the slightly laxative effect of such doses appears to be associated with the shrinkage of rectal varicosities and the arrest of a tendency to bleed at stool. Whatever treatment is employed for hemorrhoids, I am in the habit of prescribing this remedy as a prophylactic when the local application has not made the rectum too tender, for the macerated seeds are at times recognized by a slight smarting sensation at the time of evacuation.

The purpose of more definite electrosurgical treatment of individual piles is the coagulation of the blood in the pile in such a way that the clot will become organized into solid tissue, collateral veins taking care of the circulation previously conveyed by the enlarged vein.

The methods employed are: (1) Zinc puncture and ionization. (2) Anodic submucous electrolysis by puncture with an

insulated irido-platinum needle. (3) High frequency cauterization. All the methods are unipolar.

1. Zinc puncture and ionization was formerly employed in most of the author's work. It is invariably effective, but has the disadvantage that the zinc needle is not readily made so fine as to carry insulation beneath the mucous surface and thus confine the ionization to the interior of the hemorrhoid, the ionization of the mucous surface resulting in a small surface ulceration whether the hemorrhoid be internal or external. The zinc ion is theoretically contraindicated also as it is not a particularly absorbable ion and is usually extruded in a slough or serous discharge. Nevertheless, a number of cases have been successfully treated with but slight discomfort to the patient.

2. Puncture with a sharp needle made of platinum iridium, the needle having been insulated with fused hard rubber after the technic described at page 358 has the advantage of producing a clot that has no foreign ions, consisting only of fibrin, hemoglobin, etc., clotted by the released ions of phosphoric acid, etc., of the tissues. More current will be needed than when the zinc ions are used.

With the exception that less milliamperage is used with the zinc anode, the following technic will apply to both of these methods:

An external hemorrhoid may be treated with the patient in either the dorsal or Sims' position as most convenient, the dispersing cathode pad being either beneath the back or resting on the hip. If the external hemorrhoid be covered by dry skin, endermic anesthesia with cocain or a synthetic substitute should be used. If covered by moist mucous membrane the mere application of the powdered anesthetic will suffice if ten minutes be allowed to elapse before puncture.

Active Electrode.—If zinc ions be employed, the electrode for external puncture is a fine needle of this metal about 5 centimeters long, insulated at its puncture end except 2 millimeters from its point with fused sealing wax (see page 197). For an internal hemorrhoid the needle must be long enough to reach the hemorrhoid through the speculum and insulated as described.

An active electrode of irido-platinum may be made from 3 centimeters of No. 26 irido-platinum wire soldered to a longer piece of silver or copper wire, the platinum tip being filed sharp and copper end turned into a loop for attaching the light wire conductor. This needle is best insulated more permanently by fusing

hard rubber on it except the 2 millimeters of tip as described at page 358. In fact, a rather long epilation needle may be used for this purpose.

Either of these active electrode needles should, of course, be connected with the anode of the generator of direct current.

Proximal Proctoscopy.—Exposure of internal hemorrhoids is best done by the Howard A. Kelly method of air gravity distension of the rectum, with the patient in the knee-breast position, the patient's hips being supported by a nurse.

For this examination and treatment of the lower rectum by the Kelly method one needs the author's hard rubber proctoscope (Fig. 148) or a Kelly sphincteroscope, and means for lighting the rectum, either a head mirror or a small caliber miniature lamp enclosed in a glass tube (Fig. 149).

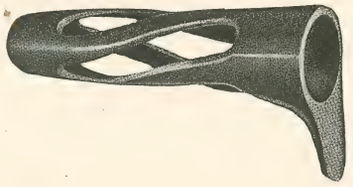


Fig. 148.—Author's Hard Rubber Proctoscope. (One-half size.) This instrument has been improved by cutting off the end, smoothing the three blades, and placing within it a well-fitting glass test tube to act as obturator during its insertion, the obturator being removed after the proctoscope is inserted.

When shortened by the removal of the solid end the blades of this proctoscope are capable of being bent slightly to a less caliber while immersed in hot water, the new curve being then fixed by immersion in cold water. A smaller glass tube may then be used as obturator.

This instrument is a little more clumsy to insert into the anus than the Kelly instrument, but the material of which it is made makes it ideal for any kind of electric treatment, including the Oudin; the spaces between the blades permit of a better view of the anal edges and the nearest portion of the rectum than full cylinders, as well as the ready treatment of morbid conditions showing between the blades without spreading of the current as would be the case with a metal instrument.

With the patient in the genupectoral position, the warmed and lubricated instrument, with obturator in place, is gently

inserted through the sphincter by a series of pressures and rotations, taking advantage of momentary relaxation of the muscle at any time. When inserted, the obturator is removed, the instrument being held firmly in place. The air rushes in and distends the rectum at once, and the hemorrhoid, ulcer or fissure may be illuminated. The powdered anesthetic is now placed on the spot selected for treatment, and allowed to remain several minutes, when the active needle is inserted into the pile until its insulation disappears within it. A current sufficient to turn the pile of a lighter color is then gradually turned on, and turned off equally gradually as soon as the change of color occurs. The power employed varies from 5 to 15 milliamperes for five to ten minutes. On subsequent days other hemorrhoids

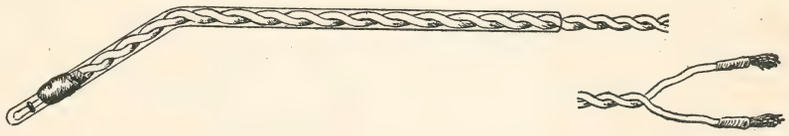


Fig. 149.—Miniature Lamp of Small Caliber for Rectal Examination and Treatment. This instrument may be replaced by one of even smaller caliber by using the miniature lamp employed to light an urethroscope of the electrically lighted variety, covered with a fine glass tube made like a test tube by a glass blower.

may be similarly treated, but a single application is all that is usually required for each; some tenderness will be felt for several weeks.

3. High frequency cauterization is inferior to the methods mentioned, as it produces a slough.

Hypertrophy of the Prostate.—In considering the indications and value of electricity in its various forms in enlargement of the prostate gland, we should distinguish as clearly as possible between conditions that are of the nature of chronic prostatitis, on the one hand, and prostatoma, or fibroid prostate, on the other. It is of course not easy to make this distinction in borderline cases, or what appear to be borderline cases (for I regard them as distinctly differing conditions), but the success of the treatment depends on the differentiation of the two conditions.

Chronic prostatitis is usually, though not invariably, a more or less late sequel of some kind of infection, whether from the urethra below or the bladder above. It is a glandular hypertrophy with hypersecretion of the prostatic glands. It is my

impression that these cases present more sensory disturbances referred by the patient to the prostate than prostatomas, and that they are more sensitive to rectal touch by the examiner.

In prostatoma, the primary lesion is the hypertrophy of the fibrous elements of the organ, and the chief symptom is apt to be interference with the flow of urine, followed soon by the secondary symptoms that assume chief importance and that may simulate prostatitis: retention of urine, cystitis, and later pyelonephritis.

Where the first mentioned condition, that of chronic prostatitis, is clearly diagnosed or reasonably suspected to exist, electric modalities are indicated and will prove of great value. This has been greatly emphasized by the successful use of the milder modalities, applied through the rectum, by Dr. William Benham Snow, of New York, after some of us had become discouraged by the uncertain results of over vigorous local treatment to the

Fig. 150. Prostatic Electrode for Rhythmic Wave Currents.

prostatic urethra. Dr. Snow and his many followers have proved his contention that cures of chronic prostatitis may follow the use of the static wave current from a multiple plate machine, and renewed the flagging interest of electrotherapeutists in this subject. The conditions cured were, of course, similar to those found in chronic metritis, uterine hypertrophy and chronic subinvolution of the uterus, the two organs being homologous. The remedy is largely the same: rhythmic currents, with a prostatic electrode (Fig. 150), gently pressed against the prostate, with the dispersing pad on the abdomen. Any rhythmic current of twenty to fifty surges per minute is also of service, applied for half an hour daily.

In inserting the rectal electrode it should be passed beyond the sphincter and be tilted forward against the gland. Some have advised that the proper apposition of the electrode to the gland should be maintained by attaching the electrode to an external tube holder resting on the floor. This makes any movement of the patient after insertion attended by discomfort and displace-

ment of the electrode. A far simpler plan is to attach a tape to the handle of the electrode by which backward and upward tension may be made on the handle, pressing the bulb against the prostate, and maintaining it in that position by pinning the tape to the clothing of the patient. With this arrangement the patient may move slightly without disarranging the contact.

But it is an open question whether diathermy, from the rectal non-vacuum tube (Fig. 151), through which 400 to 500 milliamperes of the metered Tesla unipolar current is passed, is not better in a semi-acute case.

The direct attack on the chronic glandular infection obviously offers more difficult problems than similar anti-infection treatment of the uterine mucosa. It is easy to set up a cystitis by unwise intraurethral instrumentation. My predilection is for ionization by a solution used with the soft rubber perforated

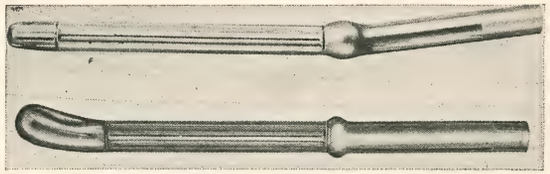


Fig. 151.—Non-vacuum Prostatic Electrodes. Much less amperage must be used in the upper tube, with its relatively small active surface, than is permissible with the lower electrode.

cathode of Russ (page 331), with a stylet rigid enough to carry the catheter tip with the perforations into the prostatic urethra when given the long curve of the Gross silver prostatic catheter. A little patience will often permit local applications to the gland of a harmless yet distinctly therapeutic nature. These applications should be made but once a week, and with tentatively small currents. Other anti-infection measures of an electric character are the vacuum tube current and diathermy, alluded to above, both applied through the rectal wall. Of late, I have employed the rectal non-vacuum tube current in prostatitis, with possibly the greatest benefit of any modality.

When a true prostatoma exists, indicated by predominance of mechanical obstruction over sensory symptoms, and later by cystitis, we are in a measure in the position of a physician who discovers a fibroid tumor of the uterus in a woman. Before considering operative measures we should give the patient the

advantage of inducing a retrograde process of growth in the tumor and shrinkage by absorption as the result of the screened, deep penetration X-ray; subject to the mere possibility of operative intervention being needed should catheter life become difficult, with its threat to the upper urinary tract. This latter consideration need be the only one demanding the suprapubic operation, for the possibility of the prostatoma being really a carcinoma in a small percentage of cases only indicates the wisdom of radiation, as neither excision nor electrothermic ionization are attractive propositions.

I leave the Bottini operation, an intraurethral hot wire cauterization of the middle lobe, popular some years ago, as well as other destructive applications through electric power, as matters of past and possibly future history, as urologists become familiar with electric power.

Impotence.—With manifest local disease of the sexual organs absent, this condition may be treated with rhythmic galvanic sinusoidal currents (page 72), with hope of improvement in some cases from stimulation of the lumbar secondary nerve centers and of the prostate gland.

The patient may lie prone on a couch with a large dispersing pad beneath the abdomen and a smaller pad, about seven inches in diameter, over the lumbar vertebrae. The rhythmic galvanic sinusoidal current is then turned on and the power brought up to a comfortable mass contraction of the muscles, varying in milliamperage in different persons from 100 to 200 milliamperes. Before the height of current is attained the active pad should be pushed up and down a trifle until the patient feels the sensory wave action in the region of the penis. After twenty minutes this part of the treatment may be ended and an active rectal electrode inserted into the rectum and a recto-abdominal application made for ten minutes, with the patient in the dorsal position and a current of from 50 to 100 milliamperes. For the latter application the Morse wave is equally effective.

Papilloma of the Bladder.—There has been a general adoption by urologists of high frequency cauterization as the standard treatment of intravesical papillomas since the value of this method was pointed out by Dr. Edwin Beer, of New York. For the technic of this procedure see page 282.

Spermatocystic Vesiculitis, Chronic.—Diathermy, applied with an active electrode behind the vesicles and the dispersing plate on the abdomen is indicated. Vacuum tube currents in

the rectum have also been used with advantage, but may possibly break in the cavity, hence the non-vacuum type should be used.

Stricture of the Urethra.—Victor Pedersen, of New York, in one of the most recent treatises on Urology [1] speaks of this method as follows:

"Electrolysis is often regarded as a disapproved method, but in the hands of experts with suitable apparatus it should be regarded as one of the accepted methods, in that its softening and relaxing action are of great advantage in selected cases. A great difficulty is that electrolysis by modern methods requires expensive and somewhat cumbersome apparatus in order to provide the variety, range and control of the currents. It cannot be properly applied by small and cheap apparatus, which might be designated as electrical or scientific toys. On the other hand, electrolysis is not to be regarded as a kind of cure-all method, but as a method with distinct limitations." [2]

The late Dr. Robert Newman, of New York, was the originator of the present, electrically correct, method of treating stricture, and devoted his life to the advancement of the method. The earlier history of the subject is well told in his contribution to the International System of Electrotherapeutics,[3] in which he also laid down the principles of treatment that are still followed. The earlier workers in this field made such mistakes as employing the anode as active pole; using too strong a current, often of unknown strength in those days of large acid cells and no meters, that destroyed tissue and created ultimately a worse stricture; using the method too often, and thus setting up irritation; and using electrodes of unsuitable shape and finish.

Omitting those portions of his rules that are now archaic due to the advances in current supply and apparatus, and assuming that the modern urologist will employ the direct current controlled smoothly by a suitable controller, preferably a wire-shunt type (page 27 *et seq.*), with a meter in the patient's circuit giving accurate readings in single milliamperes, and being certain that it is connected up properly so that the anode is really the

[1] "A Text Book of Urology," by Victor Pedersen, Visiting Urologist to St. Marks Hospital, etc. Lea & Febiger, Philadelphia, 1919.
[2] *Ib.*, p. 384.
[3] "International System of Electrotherapeutics," Bigelow and Massey, F. A. Davis Co., Philadelphia, 1904, p. G. 88.

anode and the cathode really the cathode—the rules given by him are as follows:

The cathode (negative pole) of the direct current must invariably be used as the active pole.

The electrode is a firm sound, with active bulb either egg shaped or acorn shaped, of a size about three sizes greater than the measurement of the stricture, insulated by baked hard rubber (Fig. 152). The active bulbs must be smooth and permanently attached to their staffs, preferably by brazing, interchangeable bulbs with one staff being dangerous as likely to come loose, and present a joint liable to rust. A straight stem is used for the upper urethra and a stem with a short curve is preferable in the deeper urethra.

Dr. Newman usually preferred the standing position, with patient grasping a sponge electrode as indifferent pole. With the

FIG. 152.—Dr. Robert Newman's Urethral Electrode.

patient in the dorsal position a dispersing pad connected with the anode of the apparatus is placed on the abdomen and the active electrode is connected by a light wire of ample length to the cathode. No current should be turned on until the electrode has been inserted and reaches the stricture, and the current should be turned off as soon as the bulb has passed the stricture and repassed it on the way out, as a current should not be applied to the healthy urethra.

Force should not be used in passing the stricture. The handle of the electrode is held lightly between the thumb and forefinger, or the thumb and the first two fingers.

No anesthetic is to be employed, as the sensations of the patient are of use to the operator, though a weak solution of a cocain substitute may be used in exceptional cases.

The purpose of the application is to promote absorption of the stricture, not to cauterize, burn or destroy tissue.

Weak currents, with applications at long intervals.

The current power usual is from 2½ to 5 milliamperes for five to twenty minutes, repeated once a week.

Insert only one instrument at a séance. Repetition of insertions at the same séance is undesirable.

Pain should not be produced by the manipulations.

The method should not be used in acute urethritis.

Lubrication of the instrument should be by a conducting jelly.

These rules are good to-day. To a reader of the previous chapters on the direct current in this work it is evident that, unless the active bulb is small, no destruction of the stricture is possible by 5 milliamperes in five or ten minutes, though the same current in twenty minutes would soften moist tissue in contact with a bulb of this size, whether the tissue be scar tissue or mucous membrane. The weakest power application mentioned would attract to the instrument sodium ions uniting with hydroxyl and free hydrogen, together with increased moisture in immediate contact with the metal, all derived from nearby tissue and fluids, while the chlorin that had been united with these ions is driven further into the sclerosed tissue. It is evident, therefore, that we have a soapy, lubricating, relaxation produced in the stricture when the bulb is within it that must be a great assistance in gradual dilatation, together with a direct sclerolytic action (see page 52) on the sclerosed tissue; while the secondary action should be a promotion of the absorption of the morbid tissue.

But, before the urologist employs this method he should be in full possession of the important facts of current concentration and diffusion given in Chapter II, and particularly illustrated in Fig. 10 (page 15). These show that while 5 milliamperes might be full concentration for lubrication on a large bulb, this amount concentrated on a tip presenting but half the active surface would double the concentration, and therefore become caustic.

A true cauterization, however produced, would be followed by cicatricial tissue, possibly denser than the tissue cauterized. Such cauterization should therefore be sedulously avoided in the treatment of strictures, whether they be in the urethra or elsewhere. In fact, it would help in the clearer presentation of this subject of the treatment of stricture by the galvanic current if the words cauterization and electrolysis were both eliminated, and the procedure called cathodic lubrication in the dilatation of stricture.

It is extremely likely that much of the good results from cathodic dilatation of strictures in the urethra follows the cure at the same time of ulcerations yet existing in and about the strictures, the gentle hyperemia being beneficial. This would explain the disappearance of gleet that follows this treatment.

In a personal communication, Dr. Pedersen further elucidated this subject as follows:

"In the matter of close, dense, fibrous stricture of the male urethra I think the following facts are universally admitted by Urologists.

"One does not see this type of case as often as twenty-five years ago. When I was an interne in the New York Hospital at that time, for example, each of the surgical wards was rarely without at least one and not infrequently several such cases. They usually had such complications in the bladder and upper urinary tract that the late Doctor Lewis A. Stimson operated on them without anæsthetic, in order to avoid the danger of ether or chloroform in a patient with severely diseased kidneys. This period in urological surgery marked the end of the practice of treating deep urethral lesions with caustics. By the *'porte cautisque'* globules of pure or unduly strong nitrate of silver were deposited in the urethra. This instrument had passed out of use many years previously, but the application of unreasonably strong solutions was still more or less in use. Allowing for the number of years necessary for a stricture of this type to develop itself and to cause complications, one may readily see that all these patients had suffered from the disease, its complications, and this faulty treatment, beginning several or many years back.

"The so-called electrolysis of stricture, originally developed by Newman, practically began at the end of this period of faulty treatment. As this era in treatment has been corrected, and as the whole theory and success of the management of urethritis in the male has changed and improved, one sees these cases very rarely indeed. I doubt if the ordinary clinic today sees more than one or two to the year in contrast to several or many to the month. For example, in public and private practice I do not believe I have seen more than a half-dozen cases requiring combined external and internal urethrotomy in the last five years. These are the reasons why I have never employed Newman's or analogous methods, but rely rather on the slow deliberate dilatation of the stricture.

"It is not possible in any way to dissolve the fibrosis, and the average case does exceedingly well under gentle treatment with dilatation. I mean that this treatment, other things being equal and the condition of the patient permitting, requires not less

than three months to bring the stricture up to a free caliber. After that the full caliber of the canal is established with equal gentleness and caution. When so treated very few of these strictures ever relapse if they are watched and sounds are passed once, twice or thrice a year. Of course, in the dilatation treatment of the fibrosis itself the surrounding mucous membrane is very greatly benefited by the various forms of electrotherapeutic treatment with which we are all familiar."

Thiosinamin in 10 per cent. solution administered in 15 minim doses hypodermically previous to each cathodic application has been recommended; or fibrolysin, which is salicylate of thiosinamin, may be used in the same manner as aids in the absorption of newly formed scar tissue.

The d'Arsonval current, to a strength of 100 milliamperes, has been advised, but has no scientific basis unless true cauterization is desired. A heavy insulation of the instrument is required for this current.

Ulcer of Urethra.—See Gonorrhea.

Venereal Warts.—See Condylomas.

Vesiculitis.—See Spermatocystitis.

CHAPTER XVI

ELECTRICITY IN DERMATOLOGY

Surgical Uses of Ionization—Germicidal Ionization—Electrodesiccation—Effluvation—Diathermy—Cathodic Destruction of Tissue—Cathodic Depigmentation—Anodic Solidification of Blood Tumors—Acne—Alopecia—Angioma—Boils—Carbuncle—Comedo—Cornu—Dermatitis — Eczema — Elephantiasis—Moles—Freckle—Herpes Zoster—Hypertrichosis—Keloid—Lupus—Milium—Nevus Pigmentosus—Paget's Disease of Nipple—Powder Marks—Port Wine Mark—Pruritus—Ringworm—Telangiectasis—Warts—Xanthoma.

The practice of dermatology by the modern specialist includes the use of electric power in various modalities on an extensive scale, particularly since the introduction of the X-ray, high frequency currents and actinotherapy into medical practice, though some dermatologists have made extensive use of the direct current for years. As this work does not cover the field of radiation therapy at all, special treatises being necessary at this time for its adequate presentation, and the author is not fully informed concerning the uses now being made of radiotherapy and actinotherapy in skin diseases, it is necessarily incomplete on the technic of these subjects, though the indications for their use are sometimes given. Both are exceedingly valuable in dermatology, and this explanation should be borne in mind by the reader of the appended suggestions concerning the therapy of particular conditions.

The modalities receiving what is hoped to be adequate technical consideration in this chapter, taken in connection with a previous study of the first twelve chapters of this work, are:

1. **The Surgical Uses of Ionization,** both as a means of destroying granulomas and other neoplasms of the skin; and as a germicidal application to skin surfaces more or less broadly infected by the various known and unknown organisms causing many skin diseases.

By the first technic we destroy by zinc ions from zinc needles

inserted into them the tissue of a neoplasm as a whole, including the causative organisms. This will make a small wound, as compared with no wound from radiotherapy successfully applied; but the small or large tumor is destroyed in a few minutes and by inexpensive apparatus, the action and effects of which we can accurately control—as compared with weeks or months of radiation treatment devoted to a small skin growth but flooding necessarily the interior of the body, the action of the remedy being difficult to control even on the surface. The scar from ionic destruction of a small skin growth, moreover, is always small, often finally linear after a broad destruction of surface, and always relatively inconspicuous.

These remarks are not intended as criticisms of the proper employment of radiation in skin growths, particularly in such conditions as, for instance, multiple dermic or subdermic metastatic carcinomas, or other multiple neoplasms too numerous or refractory for ionization or desiccation of any kind, as well as ordinary skin infections in situations where over action would be unimportant; but is a protest against a too prevalent habit of employing a single therapeutic agent in all conditions, in some of which other agencies are more convenient and controllable.

2. Germicidal Ionization.—By the second ionization technic, that of driving in ions in solution from compresses saturated with a weak solution of the selected ion placed under the proper pole of the direct current, or from solutions of the ion in water in which the part is immersed, we have a means of reaching and destroying germ life not only in the infected deeper recesses and ducts of the skin, but *within the cellular elements of the skin itself* by ions that are relatively harmless to skin structures though lethal to infecting organisms.

To appreciate the possibilities of ionization from solutions in dermatology the chapter on ionization in this work should be read, as a guide to a more extensive experimentation in this field than has been heretofore done. As stated by Leduc, it is inconceivable that local remedies (which enter the skin, if they enter it at all, as ions) should be expected to enter the skin from solutions unaided, and particularly from the ion-inhibiting solutions of oils and greases, when they can be driven into molecular union with germ protoplasm at once by a gentle direct current. Moreover, if one drawback to medicinal ionization at great depths beneath the skin is the time required to convey the ions

so far, the skin alone being thoroughly penetrated in a relatively short application with a weak current, this very drawback to ionization of deep structures is an advantage in the endermic application. It would seem, therefore, that the driving of suitable ions into the skin should rank as a parasiticide for skin infections only second to radiation, without the dangers to other structures that necessarily attend alpha and beta radiation.

Germicidal ionization is, of course, by no means the only effect attending the application of the direct current to the skin. Hyperemia and trophic stimulation are notable effects, which it shares with diathermy and the static spray or effluve.

Asepsis during Ionization of Skin Surfaces.—It is easy to sterilize any conducting pad used in surface applications by boiling, but the more cleanly plan is to sterilize by boiling the thin, soft metal plate described elsewhere as employed on the back of dispersing electrodes, the kaolin pad being replaced by several thicknesses of absorbent cotton, cut to fit the part, saturated with the 1 to 3 per cent. solution of the salt containing the ion, and laid over the surface. If the patient is so placed, lying or sitting, as to leave the affected surface uppermost, the saturated cotton and the thin metal plate may be merely laid on the part, the cotton pad next the skin of course and somewhat larger than the plate, the whole remaining in position by gravity. By not putting pressure on the plate less thickness of the pad is required than when they are held in position by means of bandages, provided the plate is everywhere equidistant from the skin, and an ample supply of the solution is kept under it by additions from time to time with a glass dropper. At the completion of the ionization the plate is sterilized and the pad either discarded or, if the solution is expensive, is laid aside in a glass, porcelain or enameled ware tray for this particular patient.

Surface Ionization by Local Baths.—Extremities may be readily placed in local baths in glass, porcelain or enameled ware containers, that holding the extremity for local treatment containing the ion to be driven in and the other a weak solution of common salt, or a selected ion that is driven in by the opposite pole, if both extremities are affected. Connection of the baths in the circuit is effected by looping thin strips of metal attached to wires over an edge of each container so that a broad contact is made with each solution in a part of the bath most distant

from the skin, aluminum being the best of the inexpensive metals for the anodic bath.

When large body surfaces are to be ionized the arrangement of the half-body bath as active surface and a large pad on the unsubmerged portion is effective, as described at page 190, for removal of lead from the body, the polarity suitable to the ion being connected with the water of the bath.

3. **Electrodesiccation.** — Electrodesiccation is an effective method of treatment of small granulomas that are equally susceptible of needle point zinc ionization, and at times is more conveniently done if one possesses an apparatus with the proper Oudin current. This is described at page 267.

4. **Effluvation** is the application of the static brush discharge from a moist wooden electrode or from a wire brush, the electrode being held far enough from the skin surface to eliminate sparks. This requires a multiple plate static machine. The negative pole is generally used, the platform on which the patient is placed being connected with the positive pole or anode. This application is a powerful stimulant to the surface, and if too strongly applied in one spot may even cause necrosis of the skin.

5. **Diathermy,** applied in skin affections chiefly as thermopenetration by means of the vacuum tube or non-vacuum tube electrode, is a most effective mode of producing localized hyperemia *within and immediately under the skin.* There is no doubt but that the diathermy of the tube current is more superficial than the metal plate diathermy. It is most effective when the other pole of the Tesla circuit is connected to a large metal plate on the opposite side of the body, or to an autocondensation cushion on which the patient reclines or sits. The chief indications for these medical applications of diathermy in the local treatment of skin affections is in the quickening of the resolution of indolent, subacute inflammatory nodules in or beneath the skin, in which the infecting agent is capable of being overcome by an aroused phagocytosis of the part. It should not be used for more refractory organisms, or if the infective agent has any degree of malignancy whatever.

6. **Cathodic Destruction of Tissue.**—The cathode of the direct current, as stated in Chapter IV, dissolves and devitalizes normal cells in a manner extremely controllable and dirigible, leaving a product capable of perfect absorption when the destroyed spot is protected from external exposure, as when the

insulation of the needle is thrust far enough beneath the surface of the skin and a small enough current is applied from its bare point to destroy tissue in that spot only. An instance of this is the fact that "beauty specialists" have been known to produce artificial dimples that are difficult to detect from the genuine by subdermic cathodic electrolysis, by using a needle so perfectly insulated at the part passing through the skin when in position that the puncture point healed without trace, beneath which the liquefied tissue produced a cavity and later retraction of the skin over it. This requires a fine needle and perfect insulation, else a scar in the skin will be produced. It is this method of insulated cathodic destruction of the papillæ of hairs at the bottom of the hair sheath that is described in the paragraph on Epilation, page 359, for destruction of the hair papilla without scarring the skin.

In the technic for the electrolytic destruction of moles, page 355, the external application of cathodic electrolysis is described. Scarring is here lessened as much as possible by confining the destruction of the abnormal tissue by the shape and mode of insertion of the needle, and by close attention to the immediate destructive effects in order to confine it to the abnormal tissue alone.

Cathodic electrolysis is also applied to the obliteration of enlarged capillaries in the skin, the anode not being needed in vascular tumors so small; in port wine mark; and in destruction of the secreting surface of enlarged sebaceous cysts and of retention cysts and tumors of the skin.

7. **Cathodic Depigmentation.**—The removal of colored moles, tattoo pigment and powder marks in the skin or mucous membrane is a mere question of technic and persistence. The cathodic needle accomplishes these results by either one or both of two modes. When the deposited material is insoluble, as in tattooing and powder marks, enough current must be employed to mechanically loosen the encysted material by solution of the fibrous structures that surround each granule, producing an eschar that separates and is succeeded by a scar that ultimately becomes white. In colored moles there is reason to believe that the metal basis of the pigment is dissolved by the sodium hydroxyl that accumulates at this pole during electrolysis of tissue, the metal itself being deposited on or in contact with the needle, which it may even unite with. The ions of iron, accidentally deposited in the skin from a steel needle incorrectly

used as the anode, for instance, may be drawn out of the discolored skin by using a fresh needle as a cathode. When a mole has pigment that is electrolyzable (page 33), its removal by the cathode is practically anaphoresis. In my own practice I have secured enough coloring material in this way from a pigmented nevus of the skin, when the application was made under chloroform, to discolor a 3 ounce graduate of water as the froth was wiped away with a wisp of absorbent cotton that was rinsed in the water from time to time. But the mere removal of physiologically deposited pigment in this way will only be temporary unless the pigment-bearing cells of the corium are also destroyed by carrying the cathodic destruction to a sufficient depth.

8. Anodic Solidification of Blood Tumors.—This is done by an unattackable anode needle alone, so insulated as to protect the point of puncture and all tissue outside the cavity of the angioma from ionization, permitting purely subsurface activity. As the needle is of irido-platinum and unattackable by the ionic action, no foreign ions are introduced into the sac and complete absorption is assured. The object is not only to coagulate the blood within the angioma, but to produce a sterile irritation of the cyst wall of such a nature that the coagulum and vessel wall will be ultimately turned into solid tissue.

In the following list of skin affections the electric treatment alone is referred to; it is not assumed that the dermatologist or physician using these methods will neglect the conjoint or separate use of other appropriate remedies.

Acne.—The X-ray is a successful treatment for acne, but its application should be restricted to those who are expert in roentgenology on account of the danger of permanent injury to the skin—a result that happens at times in expert hands owing to the idiosyncrasies of different skins, and that is most unfortunate when the chief reason for treatment is the improvement of the patient's appearance.

The older writers recommended the direct current with moistened pads, usually the cathode active, to produce hyperemia and increase phagocytosis; but this is now displaced by diathermy with the vacuum or non-vacuum tube surface electrode. Stelwagon [1] speaks favorably of this method, recommending that the electrode be held one eighth to one quarter inch from the

[1] "Diseases of the Skin," 8th ed., W. B. Saunders Co., Philadelphia, 1916, p. 1105.

surface, but direct application to the skin should be equally effective with a strong Tesla current and less painful.

Other methods that might be tried are: very light and brief desiccation of the individual pustules; the salicylic ion from broad absorbent cotton compresses (page 56); also the mercury ion by puncture of each inflamed sebaceous gland with an anodic gold needle amalgamated with quicksilver, and a current of ½ to 3 milliamperes with a duration of half to one minute to each gland. Both desiccation and mercury ionization must be with small currents for brief periods to avoid increasing the resultant scar.

Acne Rosacea.—See Telangiectasis.

Alopecia.—Baldness. In the thinning and loss of hair after debilitating acute infections, a symptom quite general after epidemics of influenza, the hyperemic effect of the Oudin or Tesla current on the scalp from a vacuum tube with prongs resembling a coarse comb is valuable, both for arresting the hair shedding and the stimulation of new growth. The static head spray, from a crown or brush electrode is probably even more valuable. The spray electrode is connected with the cathode directly and the patient, placed on the platform, is directly connected with the anode by grasping the conducting chain. At least a fifteen minute treatment of either modality should be given.

The same modalities may be used as an adjuvant in the treatment of idiopathic baldness of unknown origin, with less hope of benefit. Where parasitic infection is the etiologic factor there is some hope of benefit, before total destruction of the hair follicles, by the static spray technic described in the preceding paragraph, the current developing copious quantities of ozone on the surface of the skin by ionization of the air; or from some form of ionization in which a parasiticide ion in solution is driven in from the anode of the direct current. Lewis Jones quotes Magnes who obtained good results after ten applications of zinc ions. Twelve days later new hairs were observed all over the treated patches. Cathodic galvanic stimulation of the bald spots has also been used in alopecia areata.

Angioma.—Cavernous Nevus. See also Port Wine Mark. The cavernous angiomas, a type of vascular nevi, are usually congenital dilatations of the venous capillaries into intercommunicating vascular cavities so numerous that they form a blood cavity, and are most often found on the face near the ocular, nasal and oral openings, varying in size from that of a filbert

to a walnut, or larger. They are bluish, easily compressible and painless. If allowed to remain they enlarge steadily and become unpleasant deformities.

The literature on the treatment of cavernous angioma by puncture and electrolytic coagulation goes back to the middle of the 19th century, and is well summarized by Poore, of London.[1] A work by W. E. Steavenson,[2] the predecessor of the late Sir Lewis Jones in charge of one of the most noteworthy direct current clinics in the world, if not the most important, that at St. Bartholomew's Hospital, London, contains accounts of the treatment of cavernous angiomas by electrolysis.

Recent works on electrotherapeutics, such as those of Sir Lewis Jones[3] and Guilleminot,[4] treat the subject quite fully, giving two technics—the bipolar, with both needles in the tumor, and the unipolar, with a dispersing pad on the back.

Wyeth, of New York, some time ago introduced a method of coagulating these growths by the injection of boiling water or steam into the cavity, but this would seem to be less controllable than anodic coagulation on account of the difficulty of insulating a small enough injection pipe, and more liable to destroy overlying skin and thus interfere with the restriction of the action to the parts below the skin, creating an open wound and a resulting scar, the avoidance of which is the chief advantage of unipolar anodic coagulation.

Sir Lewis Jones used a current of 20 to 40 milliamperes according to the size of the growth, the anode unipolar when the growth was small, and bipolar, with multiple needles, when it was large. Guilleminot quotes Bergonie as using about the same currents bipolar for three to five minutes.

The former writer describes heavy, metallic needle holders, both for the single needle and for one or more couples of opposite polarity when multiple needles are used in large growths. This, in my experience, is less handy than very light holders of hard rubber or glass tubing for the single needle electrode, as described in the paragraph on Hypertrichosis; in fact, a stiff irido-platinum epilation needle may be used for this purpose when insulated freshly as described in the paragraph referred to (page 356).

[1] "Electricity in Medicine and Surgery," by Poore.
[2] "Electrolysis in Surgery," by W. E. Steavenson, London, 1890.
[3] "Medical Electricity," by H. Lewis Jones, P. Blakiston's Sons & Co., Philadelphia, 1906.
[4] "Electricity in Medicine," by W. H. Guilleminot, Paris, translated by W. Deane Butcher, London and New York, 1906.

When multiple needles are really needed a metal holder becomes still heavier and has the additional disadvantage of conducting any stray current to the surrounding skin should it touch it. A multiple needle holder that is light and a non-conductor may be made offhand by thrusting the needles through a flat piece of cork at the proper distance apart for the particular case, connecting them to the circuit by winding the end of the conducting wire (about No. 34 Browne & Sharp gauge) about the butt of each needle and sealing the joint with sealing wax. The anode must be irido-platinum but the cathode may be steel.

Infants with this deformity should be treated as early as practicable, as angiomas grow rapidly at this age and accidental scars produced in treatment are more likely to disappear. The age of six weeks is about the earliest that one would wish to administer chloroform for this purpose.

The application should be made a major operation as it is necessarily painful, and proper control of the action is best secured under general anesthesia, the aim being to coagulate the whole tumor at this time.

The objectives in this delicate operation are twofold: The coagulation of the blood in the tumor and ionic scarification of the dilated vessel walls with resulting obliteration of the cavity, while, secondly, the overlying skin is preserved from injury and consequent scarring. The latter consideration demands fine needles, the active anode invariably irido-platinum and the cathode a large pad. The author has found the bipolar plan unnecessary when the patient is under chloroform and the greater pain of the unipolar plan thus eliminated, the single electrode permitting of greater delicacy of control. If possible, the needle should be inserted through the healthy skin at a slight distance from the growth, confining the bare part, and therefore all action, entirely to the cavity. The current should be turned off as soon as the tumor begins to blanch, the needle withdrawn and the site of puncture painted with weak tincture of iodin. If the cavity has not been entirely obliterated the operation should be repeated six weeks or two months later.

Baldness.—See Alopecia.

Barbers' Itch.—See Ringworm.

Boils.—Furunculosis. Magnes, quoted by Sir Lewis Jones, used zinc ions from a hot solution of the sulphate on a pad, with a current of 20 milliamperes for half an hour, with quick cure. This method, and probably also the magnesium ion (page 50)

would prevent the spread of the germ. Diathermy from vacuum tube currents will shorten their duration.

Cancer of the Skin.—See Chapter XII.

Carbuncle.—Leduc's experience with unipolar zinc ionization is given at page 141. The author feels that these cases could be aborted in a few hours by placing the patient under chloroform and destroying the indurated parts widely by bipolar zinc puncture ionization, as advised at page 204 for cancer, but has had no personal experience.

Chilblains.—See Dermatitis.

Chloasma.—See Nevus Pigmentosus.

Comedo.—Sebaceous glands enlarged by retained secretions may be readily destroyed by cathodic electrolysis in the manner described for the destruction of hair papillæ at page 359 after the contents are removed.

Cornu.—Cutaneous horns are really a type of epitheliomata. Their bases should therefore be destroyed by ionization or high frequency cauterization after the removal of the horn.

Dermatitis.—The dermatitis caused by exposure to cold is best treated by diathermy, preferably the bipolar application of the d'Arsonval current with plate electrodes and a current producing comfortable warmth.

For X-ray dermatitis of moderate degree, the cathode of the galvanic current has been of great service, the moist active pad covering the affected surface with a current of 20 to 60 milliamperes, according to surface dimensions, for half an hour twice or thrice weekly.

Eczema.—Stelwagon, in chronic eczema of limited extent, with pronounced infiltration, advises the use of the cathodic needle, 5 to 20 milliamperes, as a stimulus, and states that vacuum tube currents applied for some minutes every other day are occasionally curative. The static spray is also valuable. In obstinate cases the careful use of the X-ray is curative.

In a case of acute eczematous dermatitis of the skin of the thighs and scrotum of one month's duration, in which the burning sensation was so severe that the sitting position caused agony, the author recently applied the magnesium ion (page 50), in a sitz bath, 20 to 30 milliamperes for fifteen minutes with the cathode a large kaolin pad on the back. The current, of course, did not all traverse the eroded area, but that most of it passed through the skin where the cuticle had disappeared was evident by the pain produced in the eroded area. A half hour after the

termination of the application the burning due to the disease had greatly ameliorated, and the patient sat in a car with some comfort. The next day the redness of the eroded area was less pronounced and the punctate, yellowish white points of suppuration on the inflamed surface had disappeared. The patient announced that he was seventy per cent. cured. Complete healing followed a second application of the ions.

Elephantiasis.—Aranjo, of Rio de Janeiro,[1] had treated upwards of four hundred cases with electricity. His method of treatment is as follows: He makes use of cathodic electrolysis by inserting from one to three needles, insulated except at their points, into the affected tissues with the anode on the skin at a distance. After ten minutes the needles are withdrawn and inserted in another place. Between the times of elctrolysis, daily percutaneous applications of the direct and induced currents and of massage were given, followed by bandaging with pure rubber bandages.

Epithelioma.—See Chapter XII.

Favus.—See Ringworm.

Fibroma.—Fleshy Mole. The fleshy mole is a fibroma of the skin, either soft or hard, and an entirely different affection from the pigmented mole (page 349). Though cathodic electrolysis is employed in each the technic is different. That for the destruction of the fleshy mole is as follows:

With the patient reclining in a good light, an anodic dispersing pad is placed on the skin surface, or it may be so placed on the patient's lap with a waterproof under it that the patient may place both hands on it for contact.

The needle is preferably the smallest size, half-curved surgical needle mounted in a needle holder, the half curve permitting the point to be inserted parallel with the skin surface while the handle is held at a more convenient angle. The point is inserted at one side of the base of the little fibroma, transfixing it just above the skin surface and parallel with the latter, and a current of 1 or 2 milliamperes turned on, later increased to 3 to 5 milliamperes as the sensation warrants, the larger the mole the less being the sensation. A pearly distension of the mole shortly appears, indicating imprisoned hydrogen bubbles and other products of cathodic electrolysis. The patient is asked to raise the hands, after which the needle is removed and inserted in another place, the hands are replaced on the

[1] "Atlas des Maladies de la Peau," Rio de Janeiro, 1889, p. 3.

pad and the action resumed. This is repeated until the whole of the mole is soft, swollen, and shows a sharp line of demarcation between the softened mole tissue and the healthy skin. The crust is allowed to dry after being washed with alcohol, the patient being told to permit it to drop off spontaneously, and also to allow the second crust to separate spontaneously to minimize the scar. If the hypertrophied tissue alone is destroyed the temporary red scar will finally disappear from some skins without trace. If, on the contrary, the underlying skin is destroyed a slightly depressed scar will be the final result.

Moles may also be destroyed by desiccation (page 267) from a properly constructed high frequency apparatus, the desiccation giving about the same amount of pain as electrolysis but is much more convenient. Unless care is employed to limit the action to the hypertrophied tissue alone a scar will result.

Freckle.—Cathodic depigmentation (page 349) may be used, as advised by Hardaway. If a fine cathodic needle is inserted immediately beneath the cuticle, parallel with the skin surface, and a small current is used no scar will result. Desiccation is also applicable.

Furuncle.—See Boils.

Herpes Zoster.—Shingles. The cathode of the direct current has been employed over the area of disease with a thick absorbent cotton pad, and the anode pad over the emergence of the affected nerve. The several ions should be tried, particularly those that might allay the pain. Radiant light and diathermy are most helpful, the latter by thin metal plates.

Hypertrichosis. — Superfluous hairs, sometimes found on women's faces, can be permanently destroyed only by cathodic electrolysis. This was first employed by W. A. Hardaway, of St. Louis, at the suggestion of Michel, who had been successfully removing eyelashes by this method.

The method is tedious to both operator and patient, but persistence will be rewarded by complete and permanent removal of the hair, and even without resultant scars when the insulated needle method to be described is used. It is properly applied in the removal of the conspicuous hairs that resemble mustaches and beards and not for the removal of a mere fuzzy accentuation of the normal lanugo hairs of the skin. The small size and light color of the lanugo hairs and their great number make their complete removal problematic. Partial removal only accentuates the appearance of those remaining, and possibly even stimulates their growth.

For some years I have advocated the destruction of the papilla alone by an insulated needle. This is a distinct improvement of the ordinary bare needle method, which necessarily left a scar at the site of each hair that remained throughout life. I believe also that some employ the method with the patient seated in a chair. This is less convenient to the operator than when the patient reclines on a couch with low head rest or on an operating table, with the operator sitting back of the patient's head or at one side.

A good light is required, and when much of this work is done, special spectacles with additional lenses carried on an arm extending in front of the spectacles are convenient, though a small hand lens may be held in the left hand.

Any properly constructed shunt wire controller will be efficient, this form of controller being the only one to use with the 110 volt direct current as it controls the voltage also. The meter is most easily read when the scale extends from zero to but 10 or 20 milliamperes. Should a motor-generator be used for the current source, it is well to test the proper condition of the dynamo commutator by testing the smoothness of the current on one's own hands. This may be done by seeing if 5 to 10 milliamperes passed from hand to hand on pads presents a smooth sensation and no evidence of waviness. Should this test show irregularity of this nature a dynamo repair man should be called in to re-surface the brushes, to examine the commutator for burnt-out sectors, and for regrinding the surface if it shows wear. If cells are employed, a cell collector (page 24) may be used, but the turn-on of the current will be smoother if a battery of 16 to 24 dry cells are connected in series with some form of resistance controller, such as the Massey graphite controller (Fig. 19).

The Active Needle Electrode.—The late Plym. S. Hayes, of Chicago, who wrote a most excellent little brochure on this subject, preferred a steel needle with blunt extremity, made from a jeweler's broach. Such a needle can not be coated with fused hard rubber because of the great heat. Since employing insulation for these needles I have used needles made by myself from a piece of No. 26 irido-platinum wire, obtainable from dealers in dental supplies, which is soldered to a piece of silver wire of slightly greater caliber that passes through a glass or hard

rubber tube to act as handle, the wire being sealed in the tube with sealing wax (Fig. 153) with a projecting silver end curved to make an eye for attachment of a fine wire conductor by repeated threading and twisting. After mounting the needle in the holder it is filed to a smaller caliber by a fine-cut file, the filing being towards the point, with the needle resting on a hard wood block. The actual point, and half an inch above it, should be slender, or about the size of No. 32 or 34 wire, B & S gauge; and the point should not be actually sharp but the same size as the needle; in other words, neither sharp nor bulbous, so that when it is coated as thinly as possible it will slip into the follicle with the coating without force, and yet not be so sharp pointed as to pierce the side of the sheath of the follicle too easily. One

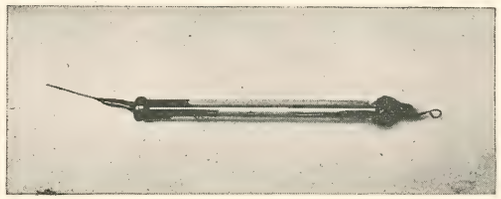


Fig. 153.—The Author's Epilation Needle of Iridoplatinum.

should really have three such needles of slightly differing size for hairs of differing sizes.

The insulation with hard rubber is done as follows: A piece of hard rubber is required, not less than half an inch thick, so that when a corner is set on fire the portion immediately adjoining is fused. Some recent specimens of hard rubber seem to fuse badly. The needle point is first burnt clean in the small flame of a Bunsen burner or alcohol lamp; a corner of the rubber is set on fire; with the needle still hot, the flame of the rubber is blown out and the fused rubber brought into contact with the side of the hot needle just back of the point, to which it will adhere. This should be repeated on the other side of the needle, the coating then, if smooth, being thinned by re-fusing lightly in the heat of the flame but not in it, with the needle so held that the fused coating will run back from the point. When skillfully done this leaves the point bare for a half a millimeter, with the coating without sudden shoulder and extending back to a nodule of rubber about a half centimeter from the point.

As this coating often lasts but a half hour, seeming to become detached under the alkaline action, and many will not learn the art of recovering, a prepared covering more readily applied has been used by some. This consists of an etheric solution of collodion with coloring matter to show more plainly. The needle, after being burnt clean in the flame, is allowed to cool and is dipped in the solution, the actual tip being then bared by scraping with a sharp knife while the needle is on a hard surface.

These combined needles and needle holders are light in weight, particularly when the conducting cord is the fine wire mentioned, and are capable of more delicate manipulation than heavy needles. *No needle holder should have a current-breaking mechanism on it* as the current should never be broken or made in the metallic part of the circuit on account of the shock and pain produced.

The Forceps.—This should be of the spring variety, but with very weak spring to assist in the delicacy of its manipulation among healthy hairs in search of the one to remove after devitalization. The jaws should be a little less than an eighth of an inch wide, and rounded at the extremity.

The Epilation.—With the patient in a reclining position with hands on the dispersing pad, and controller at zero, the needle is inserted into the follicle *in the direction of the hair shaft,* without force. A skilled operator will soon know from the touch of a light needle whether the needle follows the sheath down to the papilla or has pierced the sheath wall. The depth depends on the coarseness of the hair, being usually for large hairs about an eighth of an inch. The current is then turned on at the controller to a half to one milliampere and allowed to flow for some seconds. The tightness of the hair may be tested while the current is still flowing by gentle traction with the forceps. When sufficient current has apparently been used the patient is directed to raise the hands and the needle is removed, a small drop of cocain or procain solution being previously placed at the site so that it flows in when the needle is removed, and helps to render the other hairs removed at this séance less painful. The hair should come out without traction, showing a bulb at its end. If it remains tight the needle should be re-inserted and the process repeated.

If four hairs are removed in this way at the corners of an area an inch and a half square, other hairs within that area

will be less painful at this séance, permitting the worst hairs in this area to be removed at this time, *but hairs very close together should not be destroyed at the same séance* as this is liable to blend the actions and make the spot too sore. Actual destruction of the skin and a permanent scar has been the result of neglect of this precaution. The part treated should be washed with a weak alcoholic antiseptic after treatment, and the occasional application of hot water every few hours should be advised for the following twenty-four hours to lessen any after redness.

Noninsulated needles produce a small eschar at the site of each removed hair. Properly insulated needles produce a shot-like induration beneath the surface, otherwise one cannot readily detect where a hair formerly existed. This induration will persist from two to three weeks, and the remaining hairs should not be removed from the same locality until the indurations have disappeared.

Insulated needles develop cracks in the insulation at times during the treatment. These permit a surface burn to form, and the sensation then becomes so much more acute that a forewarned patient can always announce the presence of the leak. When this happens the needle should be recoated.

Towards the end of the séance, which should rarely last longer than a half hour, the current may be increased to 2 or even 3 milliamperes with but little increase of pain in the anesthetized area. Otherwise the controller may be left at a given point and the current turned off and on by the hands of the patient on the pad. The current should always be turned off in this manner by the patient's hands before the needle is either inserted or removed.

Keloid.—A keloid is an overgrowth of scar tissue of unknown cause. It is probably due to an organism. Diathermy from vacuum tubes has been successful in some small growths. The X-ray and radium have also been successful. Hardaway urged cathodic electrolysis with the needle to destroy the growth, the technic being that of the skin fibroma (page 355). In the few instances in which they have appeared in scar tissue after the destruction of carcinoma I have destroyed them readily by a bipolar zinc ionization under local anesthesia by the technic given at page 204.

Lupus.—Tuberculosis of the skin is now generally placed under radiation treatment, or in its milder forms actinotherapy, the latter having been first used by Finsen for this purpose.

Both of these methods are peculiarly adapted to broad surfaces, especially in the variety known as lupus erythematosus.

For the treatment of distinct nodules or definite growths of this nature nothing equals bipolar zinc ionization as described at page 204. This should be used boldly for all nodules of considerable size, while the small ones can be readily destroyed by the unipolar technic. After this has been done the patient may be placed under one or other of the radiation methods.

Cathodic electrolysis was formerly used in this condition, and some useful results published.

Milium.—Milia are the small, rounded, whitish or pearly non-inflammatory elevations of the cuticle of the face, generally near the eyes. They are retention cysts of the sebaceous glands, and are readily removed by puncture, evacuation of their contents and cathodic needle cauterization with half a milliampere to one milliampere or electrodesiccation may be used.

Mole.—See Fibroma of Skin; also Nevus Pigmentosus.

Mother's Mark.—See Port Wine Nevus.

Nevus Pigmentosus.—See also Cavernous Angioma. The first step in the treatment of the pigmented mole that contains hypertrophied hairs in addition to the pigmentary deposit is the removal of each hair by the cathodic needle, it being unnecessary to use insulation on the needle used in the pigmented area. As soon as the hairs have been cleared from an area cathodic depigmentation should be done over the same surface, as described at page 349. If the nevus be in the skin of a child, chloroform or other general anesthetic should be employed with the patient lying on a large warm anodic pad. The active needle is a half-curved steel surgical needle of small size attached to a light holder without current break. It is inserted beneath the epithelium of the nevus parallel with the surface, and with a current of 15 to 50 milliamperes can be gradually swept sidewise through the nevus just beneath the epithelium without breaking contact, loosening the coloring matter, which comes away in the watery, soda and hydrogen filled froth, the latter also making the sweeping movement of the needle edge possible. This is wiped away as the action proceeds in order that progress may be estimated. A delicate judgment is needed to decide how long the needle should remain in one spot—certainly until it is clear of color and at least half of the thickness of the skin is changed to a translucent or horny color, for we wish to destroy the pigment-bearing cells of the corium, even if a white scar is

the ultimate result. The whole of a nevus of moderate dimensions may be destroyed in this manner under general anesthesia at one operation. After the application the part should be dressed with dilute zinc oxid ointment or other protective ointment daily until healing has been secured.

Paget's Disease of the Nipple.—This condition should be regarded as an epithelioma of the milk ducts, and treated either by Roentgen therapy or electrocoagulation, page 204.

Powder Marks.—The technic given above for the depigmentation of nevus pigmentosus should be carried out to the point of dislodgment fo the powder grains, as described at page 349. Local anesthesia may be used in persons other than children, but good work can only be done under some effective form of anesthesia.

Port Wine Mark.—These are congenital angiomas of the capillaries of the skin. As the multiple tiny angiomas of which the nevus is composed are within the texture of the skin itself instead of beneath it, a different technic is demanded than that for cavernous angioma. Surface scarring is essential. The cathode is usually employed as it is vascular destruction that is aimed at rather than blood coagulation, a multiple point electrode being sold for multiple cathodic puncture at right angles to the surface. Such an instrument may be devised offhand by passing a number of fine steel sewing needles of small size through a thin piece of cork with the points projecting an inch beyond the cork, and threading the eyes of all the needles with a single fine copper wire to act as conductor.

Anesthesia is here also wise as the multiple punctures are quite painful. With dispersing anode pad in place, the multiple electrode points are pressed slightly into the nevus and a current turned on that will whiten each needle prick in a few moments. When sufficient action at these spots has apparently been obtained the current is turned off, the needles shifted to another spot—possibly straddling the previous punctures—and the action repeated until the whole surface has been made rather raw. It is then dressed with an ointment and further treatment postponed for several months, when any spots remaining are electrolyzed in the same manner, or with a single needle.

Port wine mark may also be destroyed by actinotherapy through direct application of the mercury vapor lamp, the effect being carried to the point of producing a blister.

Pruritus.—The usual physical force employed in the treatment

of the intense regional pruritus that often resists ordinary treatment is the X-ray. As this has elements of risk by reason of the surface raying necessary, a recent report by William A. Rolfe, of Boston, of the value of ionization with parasiticidal ions in this condition is of much interest.[1] Dr. Rolfe had treated thirty cases, mostly in the anal region, during a period of observation of six months, in private work and at the Boston Dispensary.

His technic was, first, the diffusion of the zinc ion from a 2 per cent. solution of zinc chlorid on an anodic pad carefully adapted to the surface, with the patient in the Sims' position. The applications lasted fifteen to twenty minutes, the dosage being not over 10 milliamperes. After two zinc ionizations with intervals of one or two days, he employed the iodin ion from a cathodic pad saturated with Lugol's solution of iodin diluted with four parts of distilled water. This was continued twice or thrice weekly, with less current strength than when diffusing the zinc ion. Of the results he reports as follows:

"The results of this treatment have been very encouraging, not only from the fact that the itching has been relieved after the first application but what is still more important, the condition of the skin began to improve immediately. In six cases in which the skin was thickened, dry and fissured, a return to normal appearance was noted after twelve or fifteen treatments, given twice a week. As the condition of the skin improved the itching diminished, and in the six cases cited above over three months have elapsed since the disappearance of the pruritus.

"It was observed that after each treatment there was a great diminution of the itching, amounting in some cases to a practical cessation, which lasted for about two days. Upon its recurrence it was less intense and more controllable, not requiring as much digging and tearing at the parts as before. In twelve cases the skin showed very marked improvement coincident with a great lessening of pruritus, so much so that the patients reported an ability to sleep. The remaining cases are making satisfactory progress.

"During the treatment of these cases no antipruritic ointment or washes of any kind were employed, but strict cleanliness of the parts was insisted on. Patients were instructed to wash the parts with hot water and soap after each defecation and always before retiring. This is a most important consideration in the treatment of this disease as it tends to prevent re-infection. In

[1] *Boston Medical and Surgical Journal,* August 14, 1919.

cases in which the skin was moist and macerated a simple talcum dusting powder was ordered."

Ringworm.—The accepted treatment of ringworm at present is the X-ray in capable hands. If this is unavailable or undesirable on account of the depilatory action of radiation, ionization with a parasiticide ion will be found to be effective. The mercury ion, diffused from a three to five parts per thousand of bichlorid of mercury solution under the anode has been successfully used by Drs. E. Claron and G. Gevaert, of Brussels.[1] Other parasiticide ions may also be used.

Shingles.—See Herpes Zoster.

Tattoo Marks.—See technic for removal of powder marks.

Telangiectasis.—Spider Nevus. These are capillary varicosities, usually acquired on exposed surfaces, as the nose or cheek, or congenital when radiating, as in so-called spider nevus. The best treatment is cathodic electrolysis with a fine needle inserted in each capillary, the patient being in a good light with anodic pad on the surface elsewhere. A current of one-half to one, or even 2 milliamperes, is allowed to flow for five to thirty seconds in each vascular dilatation, selecting the arterial end of the dilatation if possible.

Warts.—Verruca. Cathodic electrolysis or mild desiccation was the electrical method of treating warts until the value of the magnesium ion (page 50) for the destruction of the parasite was discovered. As the latter is painless, and electrolysis much more painful than when used in a skin fibroma, the advantage of the magnesium ion is evident. In plantar warts that are so painful as to resemble corns the magnesium or salicylic ion should be preceded by paring off the horny layer.

Xanthoma.—This yellowish, flattened growth about the eyelids is readily removed by cathodic electrolysis in a depigmentation application (page 349), though anesthesia may not be needed, currents under 5 milliamperes being effective. As this affection is at times associated with diabetes the proper tests should be made and the treatment not used in the presence of glycosuria.

[1] Hayes in "International System of Electrotherapeutics," p. G. 228.

CHAPTER XVII

ELECTRICITY IN DISEASES OF THE NOSE AND THROAT

Radiant Heat and Diathermy in Acute Inflammation of Nasal Cavities—Ionization of the Nasal Mucous Membrane—High Frequency Treatment of Infected and Enlarged Tonsils—Destruction of Benign Tumors within the Nasal and Pharyngeal Cavities—Direct Current Coagulation within the Pharynx—Stricture of the Oesophagus.

Before preparing this chapter a number of standard works on rhinology and laryngology were consulted in order to learn the present attitude of practitioners in these specialties on the use of the physical forces in treatment. As a student of the older literature on this subject, summarized some years ago by Sajous in his article in the "International System of Electrotherapeutics," and with a considerable personal experience in the employment of electrocoagulation methods in nasal new growths, I was disappointed to find no mention of the subject in most of the exhaustive treatises, unless one improperly considers the cautery knife a portion of it. The attitude of one author, nevertheless, would be sufficient warrant for this chapter, aside from the author's personal experience. Herbert Tilley states at page 333, under the heading of "electrical measures" in the treatment of nonmalignant new growths in the nasopharynx:

"In view of the profuse bleeding which often occurs when an attempt is made by surgical measures to remove a tumor with a broad base of origin, Delavan (Trans. Amer. Laryn. Assoc., 1911) has advocated a return to the methods of electrolysis, combined if necessary with the galvano-cautery or galvano-cautery snare. These measures have been successfully practised by Voltolini, Lincoln, Price-Brown, and others.

"In this way the disease can be treated through the nasal passages, the bleeding is practically negligible, and with patience on the part of the surgeon and the sufferer many cures have been established.

"The disadvantages are—(*a*) That electrolysis alone may require many applications, and since it is very painful a general anesthetic may be necessary for each séance; (*b*) the surgeon must possess some knowledge of the technical management of the current or be assisted by some one who is thus equipped, a matter of considerable difficulty when a long course of treatment may be necessary.

"Frank Rose has successfully removed a naso-pharyngeal fibroma by diathermy; it is not unlikely that in the near future this method will often replace radical surgical operations." [1]

In another portion of his work the same author gives the technic for the destruction of intranasal malignant growths by electrocoagulation.

The disadvantages of electrical methods in benign naso-pharyngeal new growths stated by this author are not so great as they seem, for (*a*) an operator skilled in both rhinological and electrosurgical technic need operate but once for a benign tumor in this situation. Surgeons should correct an obsession that the only force of nature with which a "radical operation" can be done is sharp steel. As for the second disadvantage (*b*) there is no reason why the rhinologist in particular should not add electrosurgical technic to his other attainments. It is to assist in this achievement that no rudimental technic is given in this chapter, compelling the rhinological student to study the preliminary chapters in this work for such knowledge of handling these forces as can be conveyed in books.

The earlier employment of electrolysis in intranasal affections lost popularity for very definite reasons. Cocain had not then been discovered or was but little used, and ionization was unknown. The chief work at the time was the electrolysis of hypertrophies and neoplasms without local anesthesia of any kind and by the unipolar galvanic current. The pain attendant on such procedures in noncocainized mucous membranes was augmented by the unpleasant cerebral vertigial effects incident to direct current waves in this region, widely spread as they were by the two poles being so far apart.

Local anesthesia, increased by ionization when the active pole is the anode, together with the perfection of apparatus for proper control of voltage as well as milliamperage without shock, has lessened the discomfort of unipolar applications with mild cur-

[1] "Diseases of the Nose and Throat," by Herbert Tilley, H. K. Lewis & Co., Ltd., London, 1919, p. 333.

rents, turned on and off without shock or wave effect; while we have learned that the bipolar technic of direct current electrocoagulation is both readily applied and the most effective mode of destroying benign and malignant growths within these cavities, with a spread of current so slight that it may be employed with large currents without the production of vertigo.

The field of these physical forces in oto-laryngo-rhinology can only be determined when skilled laryngo-rhinologists regain a familiarity with electrosurgical technic, but the following possibilities deserve attention:

1. **Medical Radiant Heat and Diathermy in Acute and Subacute Inflammation of Nasal and Accessory Cavities.**—Acute coryza is greatly benefited by radiant light and heat from low candle power lamps. The patient reclines on a couch or bed with

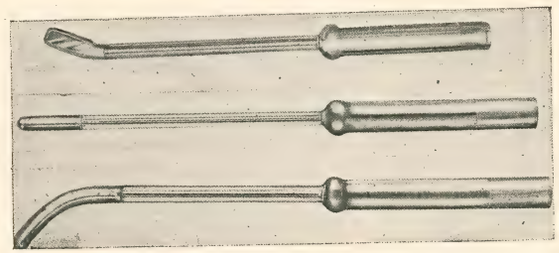


FIG. 154.—Non-vacuum Tube Intranasal Electrodes.

the eyes covered by a spectacle-shaped piece of tinfoil or thin tin-and-lead alloy so shaped that it covers each eye with a narrow connecting bridge over the nose. A 25 watt to 60 watt incandescent lamp mounted on a stand resting on the floor or a nearby table, with the ordinary reading reflector attached, is brought close to the brow of the patient and turned on for an hour at a time, once or twice a day, the light being turned off temporarily at the key by the patient from time to time when it becomes too hot.

The same technic, or that of non-vacuum tube thermopenetration, would doubtless be valuable also as an addition to other measures in subacute inflammatory conditions of the accessory sinuses, and of the middle ear, being directed against the ear in the latter condition. This technic would seem to be better than diathermy with metal plate electrodes when a broad surface is

to be reached, though the vacuum tube thermopenetration is a valuable external application.

Diathermy may also be applied within the nasal cavities by employing the Tesla current with a metal electrode inserted within the lower meatus, if the electrode be so insulated that the active surface is entirely within the cavity, otherwise most of the current seeks the external edge of the nostril.

I have also had good results in subacute inflammatory conditions from the curved, flattened insulated intranasal non-vacuum tube electrode passed into the nasal cavity through the nostril (Fig. 154), and from the curved cylindrical vacuum tube passed a slight distance within the external meatus of the ear.

Special care must be employed in using high frequency currents to see that the conducting cords do not come into contact with the patient, and that in holding the electrode in place by the handle he should not touch the external metal part of the holder that is charged by the current. To hold these high frequency electrodes in position in nasal and aural applications is most tiresome to the patient or operator, an appropriate position and an arm rest being necessary, and the manufacture of instruments with so small an exterior that they may be guyed in place by a strip of adhesive plaster or otherwise would permit of more comfortable use of these currents.

2. Ionization of the Nasal Mucous Membrane.—The field for the use of the various germicidal, tissue stimulating and sclerolytic ions (see Chapter V), must surely be a large one in chronic hypertrophic rhinitis, rhinitis sicca, and chronic atrophic rhinitis. Here the rhinologist has an advantage over other specialists, of ready and direct application of the ion-containing solution to the seat of disease after previous local anesthesia, and may observe the results by direct vision.

The active electrode for medicinal ionization should be light in weight in order to be self-retaining; slender, to enter the inferior or middle meatus, and bent into a very small shepherd's crook at the tip to retain the absorbent cotton covering and present a curved surface at its end.

It may be made of any wire for use with ions that are dispersed from the cathode, such as iodin, chlorin and salicylic acid.

When used for the copper ion a copper wire is proper; for the zinc ion a zinc strip, cut from $\frac{1}{64}$ inch or $\frac{1}{32}$ inch zinc plate with tinner's shears (the zinc instrument, slightly wider than a

wire, may be made to retain the cotton at the very end by slight barb-like notches made in it with scissors); and for other cations an aluminum wire may be regarded as practically unattackable, being attacked chiefly by alkaline ions, and even then forming only alumina, an inert substance that would interfere but little.

It is hardly practicable for manufacturers to carry these electrodes in stock as the insulation must be kept in order by the user in any case, and their construction from pieces of wire or strips of zinc is simple (Fig. 155). They may be insulated in two ways: by fusing sealing wax on all portions liable to come into contact with the patient except at the active tip, or by passing a thin soft rubber tube over them to the desired point.

The conducting wire should also be as light as possible, as the instrument should not be dragged upon or move out of place

FIG. 155.—Electrode for Intranasal Medicinal Ionization.

during movements of the patient's head. The conductor meeting this condition is a sufficient length of No. 34 or 32 B & S gauge cotton-covered copper wire, attached to the outer end of the electrode by simply winding it around the wire and covering the joint with a drop of hot sealing wax.

Details of the Medicinal Ionization Application.—These ionization applications are best made in the sitting position. As the current is weak, any ready-made dispersing pad of reasonably large surface may be slipped down the back, the clothing being protected from moisture by a waterproof back of it. The local anesthetic is applied in the usual way.

The active electrode is covered with a wisp of cotton twisted in place over the active end and, the anesthetic having had time for osmotic diffusion, is inserted into the portion of the cavity desired with the aid of a headlight. The conducting wire is then either hooked over an ear or guyed to the forehead by a piece

of adhesive plaster, as shown in Fig. 71, page 151, the wire being in a loop of the plaster so that it does not touch the skin, that might be moist enough to render its cotton covering a conductor. This disposition of the conducting wire ensures against accidental dislodgment of the electrode during movements of the patient's head, and also supports the outer portion of the electrode.

The current is then turned on slowly at the controller to the strength bearable by the patient, varying from 3 to 10 or 15 milliamperes. The usual duration of such an application is fifteen minutes, after which the current is turned off with equal care to avoid a shock before removal of the electrode, as a sudden turn off is as unpleasant to the patient as a too sudden turn on.

3. Destruction of Benign Tumors within the Nasal and Pharyngeal Cavities.—Benign tumors within the nasal cavities are most easily destroyed by high frequency coagulation because but a single electrode is needed in the cavity with this current.

Electrocoagulation within the Nasal Cavity.—In benign growths of small size destruction under high frequency coagulation may be done under cocain or novocain anesthesia. The d'Arsonval current is employed, from an apparatus of such high frequency that no wave effect is produced on nerve or muscle, heat being the only action, and this being bearable if the growth has not too deep a site.

A large dispersing plate of thin metal is placed next the skin of the patient's back with the conductor well insulated from the patient, and attached to one pole of the d'Arsonval circuit.

The active pole in attacking a small, solid, nasal growth is best with a multiple point for greater contact with the growth. The instrument is similar to those depicted in Fig. 132, page 273, with a fine piece of multiple strand picture wire instead of a single wire. The active ends of wire should be spread a trifle to cause separate punctures in the neoplasm.

With the current at the apparatus turned off at the power switch and spark gap, the electrode is guided with gloved hand into position with the head light, and is thrust into the tumor to the full depth of the bare points. The current is now turned on at the power switch and the spark gap by an assistant in the order mentioned, and a current of 100 to 250 milliamperes turned on gradually by widening the spark gap and using the rheostat. The tumor will blanch immediately, and in a few minutes will be deeply cooked.

The electrode should not be removed until the current has

been turned off at the main power switch, as painful sparking may occur unnecessarily. With the current off the electrode may be removed for swabbing out any froth and estimating results by vision, and the action repeated as seems necessary.

Whether the whole growth be devitalized at one sitting or at several depends on its size and situation. A benign growth may properly be removed at several sittings, with much diminution of its size on the second or a later day after each application, but malignant growths should be destroyed at one operation if possible, curetting the dead tissue away as it is coagulated.

Electrocoagulation within the Pharynx.—Small benign growths within the pharynx, adenoids or diseased tonsils may be treated in the same effective and bloodless manner by the method detailed above, the effectiveness of brief applications of high frequency coagulation being of special value in a situation where gagging and other signs of discomfort dictate a brief application, renewed from time to time. Oudin desiccation with the electrode shown in Fig. 131 is probably less painful.

4. High Frequency Treatment of Infected and Enlarged Tonsils.—Frederick M. Law, of New York, read a paper on this subject before the American Electrotherapeutic Association in the early nineteen hundreds, followed by recent contributions from Clark, McFee and others. The consensus of opinion of those applying the method skilfully is that these applications should replace tonsillectomy in the great majority of cases.

The question of choice between electrodesiccation and electrocoagulation, and the technic of each are important.

The earlier reports indicate that the operators confined their work to electrodesiccation, preferably with the unipolar Tesla current when the organs presented abundant diseased tissue, or the Oudin when the organs were not greatly enlarged. They reported uniformly good results in the restoration of the remnant of the gland to health, the maintenance or restoration of the voice to normal, and the restoration of the general health impaired by the infection. The only drawback to this method in the opinion of some is the necessity for repeating the application a number of times to ensure permanent results, particularly if the diseased follicles have not received the thermal sterilization to the bottom of the crypts. But this disadvantage is more apparent than real. The electrodesiccations are office treatments that are disagreeable but not very painful; the patient remains ambulant between treatments; and since the purpose of the surgeon is properly a removal of the disease but not necessarily

of the tonsil, the result that accomplishes this without sacrifice of the organ is worth repeated effort.

Other surgeons of late, under the prevailing obsession that all tonsillar tissue should be removed, have employed electrocoagulation with unnecessarily destructive effects.[1] If complete destruction of the tonsil is ever justified in these benign conditions a skilful employment of electrocoagulation should be preferable to excision since it is bloodless, not to mention the advantages of sterilizing in situ a germ nest demanding these extreme measures.

Technic of Electrodesiccation of Tonsillar Crypts.—We may select the Oudin or the unipolar Tesla current of the best type of high frequency generator (one that produces currents that are free from painful faradic effects), according to the condition of the tonsil, the Oudin giving less intense heat, but sufficient when concentrated at the tip of a fine needle to sterilize crypts not too deep. Where deeper sterilization of crypts is desirable the unipolar Tesla may be employed. This gives not only a hotter air arc, but some electrocoagulation by direct contact with moist tissue, permitting effective action with the fine needle inserted within the follicles.[2]

The foot switch, while almost indispensable, cannot replace an assistant in the proper making of this application, as an assistant will be needed to adjust the spark gap and resistance switch as we need more or less power as well as to turn the current off at the power switch instantly in the absence of a foot switch should the patient gag.

The fauces should be thoroughly swabbed with a cocain solution seven to ten minutes before the application, the patient being instructed not to swallow it but to spit out all remnants of the solution as soon as the swabbing is done.

The author prefers the recumbent position for the patient with an overhead light, but most operators place the patient in the usual throat treatment chair and illuminate with a head mirror.

[1] Vide Novak, Journal of the American Medical Association, June 23, 1923.

[2] It may be wise in this place to emphasize again that an important difference between electrical desiccation and coagulation, in addition to that of lesser and greater currents, is that desiccation is accomplished by a minute arc of electrons and heated air between the electrode tip and the tissue, while coagulation demands actual contact with or penetration of the growth by the tip and therefore more amperage, the heat producing air resistance being replaced in the latter instance by the lower resistance of the body or tumor tissues.

With the glass electrode bent at angle of about forty-five degrees shown in Fig. 131, page 273, attached to the Oudin terminal by a conductor that cannot touch either the patient or the operator, and a towel or pillow so disposed if necessary that it will prevent the operator coming into contact with the patient's body or face, the assistant sees that the power switch is open and the apparatus arranged for least current; the patient is directed to retract his tongue himself by means of a properly curved hard rubber retractor, Fig. 113, page 235. The operator may retract the soft palate if necessary with a slender, curved glass rod, as suggested by Plank, of Chicago, rest the tip of the electrode on the spot to be desiccated, direct the current to be turned on for a few seconds during which the point is raised the few millimeters necessary for desiccation.

Should gagging cause displacement of the point of the electrode the power should be turned off instantly to avoid unnecessary burns of normal structures and the procedure repeated in a few moments. By accustoming the patient to the weaker current at first, and allowing removal of the retractor between times for rest, an opportunity will soon be found for thorough whitening of the diseased spots, the action being carried to the depth of a few millimeters.

One or more portions of the tissue, and either one or both tonsils, may be treated at each séance, with reapplications to apparently diseased spots once a week, and later at greater intervals until the tonsils appear to be healthy. The longer intervals between the later treatments are to permit healing of the small wounds and a better estimate of the presence of remnants of the infection. From one to three months has sufficed for a cure in the author's experience.

Technic of Electrocoagulation of the Tonsil.—The same technic is employed in electrocoagulating the tonsil as that given above except the employment of the metered d'Arsonval current in electrocoagulation, with a large plate in close contact with the back and connected with the opposite pole. The active electrode is inserted into the tonsillar tissue itself and kept there during the few seconds required for 200 to 500 milliamperes to produce blanching of the tissue, when the power should be turned off promptly at the foot or power switch. Several of such punctures may be made, but none more than an eighth of an inch in depth unless the organ is greatly enlarged.

After Treatment.—The after treatment of electrodesiccation

of the tonsil is unimportant, and after electrocoagulation need consist only of an antiseptic mouth wash, unless much tissue has been destroyed when rest in bed under observation may be advisable. Sloughs should be allowed to separate spontaneously as attempts to remove them might cause hemorrhage.

5. Direct Current Electrocoagulation within the Pharynx.—The active anodes and the cathode are inserted into the growth either as one of each for small growths, bound together at a proper distance apart with rubber bands, or as a number of anodes inserted separately around the periphery of the growth with a single cathode in the center, this use of more anodes permitting more current to be driven in. Too small an area of contact of the anodes causes a dryness at their immediate sites that slows down the current. Repeated attainment of a boiling temperature with a thousand or more milliamperes, interspersed with turning off, swabbing out, and replacement of electrodes, will eradicate a large growth in about a half hour. This method is, however, now superseded in the pharynx by high frequency electrocoagulation. Some examples of the use of the older method, before the development of high frequency, will be found in Chapter XII.

Stricture of the Esophagus.—I note that no mention is made in recent treatises on Nasorhinology of the assistance to dilatation of stricture of the esophagus that results when the metal bulb of the bougies used in nonmalignant stricture is made the cathode of a weak direct current. The relaxing and lubricating effect of 3 to 10 milliamperes on fibrous stricture will greatly assist the mechanical dilatation. It should not be regarded as a method of treatment for this stricture, for a strong current that would dissolve the stricture would be of but temporary benefit, an equally tight stricture following after healing, but as a valuable assistant to mechanical dilatation with graduated bougies if a weak current is used and the active olive is the cathode.

An ordinary bougie with metal tip can be converted into an electrode by covering the shank with soft rubber tubing and attaching a fine wire to the proximal end of the metal shank by simple winding and twisting to act as a conductor of the current. As such a metal tip is much larger than those used in urethral strictures as much as 10 to 15 milliamperes may be used for short applications.

CHAPTER XVIII

ELECTRICITY IN OPHTHALMOLOGY

General Considerations—General Technic in Eye Applications—Surgical Uses of Electricity in Ophthalmology—Germicidal Ionization—Trachoma—Ulcers of Cornea—Tuberculosis—Diathermic Stimulation—Sclerolysis—Stricture of Lachrymal Duct—Destruction of Ocular Tumors—Pterygium—Tarsal Cysts—Trichiasis—Relief of Chronic Inflammation—Vascular and Tissue Stimulation—Muscle Stimulation—Cataract—Conjunctivitis—Epiphora—Iritis—Keratitis—Optic Atrophy—Retinal Hemorrhage—Retinitis Pigmentosa.

General Considerations.—A chapter on electricity in ophthalmology by one who is in no sense an ophthalmologist, and with an experience, outside of malignant growths of the orbit, of but a few referred cases of intraocular conditions, would seem to be out of place. That electrophysical advice is needed by ophthalmologists is very evident, however, when one reads the literature on the subject collated by Alleman [1] and Coleman [2] which leaves an impression that some of the clinical reporters possessed a poor comprehension of the physical indications of modalities employed. The present chapter is arranged to be a suggestive guide to the practitioner in this field in the selection of modes of electric force; to review electric modalities from the point of view of their physical qualities as indications of their therapeutic effects in this specialty; and to guide the ophthalmologist to the proper technic in their application.

The development of direct current and diathermy technic in the more ordinary ocular affections of a chronic nature, particularly as an improvement on other remedies in the minor surgical affections of the lids, conjunctiva and ocular walls, will not attain to its highest value until ophthalmologists master the

[1] L. A. W. Alleman, New York, in "International System of Electrotherapeutics," edited by Bigelow and Massey, F. A. Davis Co., Philadelphia, 1904.

[2] W. Franklin Coleman, Chicago, in "System of Ophthalmic Therapeutics," edited by Casey A. Wood, Chicago, The Cleveland Co., Chicago, 1911.

technic themselves as an addition to their special training. Roentgen and radium therapy properly involve reference of cases to special workers in these lines, while major electrocoagulation surgery in malignant growths in or near the orbit may well invite skilled coöperation until the technic of this work is understood by the ophthalmic surgeon, but in the minor surgical conditions in which electricity may replace less effective remedies the ophthalmologist must take it up with understanding himself or it will not be done properly.

General Technic in Eye Applications.—The rule that the electrode or electrodes should be in position before the current is turned on, and be held steadily in position until it is turned off, is even more necessary in eye applications than elsewhere because of the extreme sensitiveness of these parts. Older writers, with imperfect apparatus, advised that the current be tested on the tongue first, as offering similar resistance and sensitiveness. When modern shunt controllers, which control the voltage as well as the amperage (page 27) are used no such precautions are needed, but the operator should always glance at the controller handle or spark gap to see that it has not been left turned on after the last time it was used before putting the electrode in place.

No foot control or other apparatus for sudden applications or interruptions of the circuit are permissible, as, except for muscle stimulation, eye applications are smooth, continuous applications of the modality, controlled entirely by mechanism actuated slowly by hand. Galvanic waves and galvanic sinusoidal waves produce the "electric flash" stimulation of the retina, though this has no remedial effect so far as I am aware, being merely a discomfort—though possibly of value in testing the retinal response. A small flash may be produced by non-galvanic rhythmic currents that have considerable volume in their alternations, but the faradic current does not elicit this response.

This physiologic stimulation of the retina may be produced by the current wave falling on the retina itself, but it is usually the result of a reflex arc of which some branch of the trigeminal nerve is the other leg, as was proven by failure to elicit it in a case of my own some years ago as long as both poles were kept within an anesthetic area on the patient's forehead.

Eye applications of electric modalities may well be placed in one of two classes which should be considered in connection with

its group, both because of a similarity of technic in each class and because, at the present moment, the procedures of proved value are all surgical or minor surgical, while the experimental field lies mostly in the medicinal applications to intraocular conditions.

SURGICAL USES OF ELECTRICITY IN OPHTHALMOLOGY

The surgical uses of electricity in eye affections present a fruitful field for the skilled worker. The results are definite and immediately evident. This is true even when we eliminate all reference to such contributory relations of electricity to the subject as the production of magnetic power for the removal of steel and iron fragments from the eye, the lighting of lamps, and the creation of heat in the cautery knife, for information concerning each of which the reader is referred to works on general ophthalmology. The surgical uses to be described are the effects of the polar action of the direct current and of the Oudin or Tesla current at electrodes that are in immediate contact by surface rest or puncture with the seat of disease, rather than by transmission through the closed lid, the usual method in medical applications.

As these surgical uses are confined to the direct current and the high frequency current, the ophthalmologist's outfit must include the best apparatus of each kind in order that the dosage may be accurate and applied without shocks.

For the direct current the shunt wire controller (page 27) is needed. The larger the drum of this controller the more delicate is the control. The meter for the minor surgery to be described should have a scale in which a half milliampere is indicated or can be ascertained, in a total scale of 10 or 20 milliamperes. For major electrocoagulation a scale from zero to 2500 milliamperes is needed.

The high frequency transformer should supply an Oudin current capable of desiccation without producing other sensation than heat.

The surgical effects or methods in ophthalmology may be divided into the following subvarieties: germicidal ionization; sclerolytic effects; dilation of strictures; and destruction of tumors.

GERMICIDAL IONIZATION

For a fuller statement of the principles of germicidal ionization the reader is referred to Chapter V. The application of this

method to infected glands of the eyelids is a mere matter of delicate technic, usually with a needle composed of the metal or substance to be ionized. In the treatment of ulcers a blunt instrument of the metal to be ionized is held in contact with the ulcer for the two to five minutes needed, in both cases the parts to be cocainized as usual.

A very important point in the selection of the ion in eye cases is that, where the spot is conspicuous, as in the conjunctiva over the eyeball, no ion should be used that will leave a permanent mark or stain, such as silver, iron and possibly copper, though the last is more soluble. An ion that causes sufficient irritation that a minute slough is the ultimate outcome should not be used on the cornea or the sclerosa either, though it is invaluable in purulent pockets elsewhere, such as in the lids, in which a zinc needle amalgamated with mercury, or without mercury, is surely the most effective mode of treatment, the subsequent irritation of the zinc deposits being over in a few days, and doubtless is itself of great value in arousing tissue resistance.

Trachoma.—The patient lies on a couch or operating table with the head in a good light, and a dispersing pad connected with the cathode binding post of the controller of direct current beneath the shoulders or beneath the hands, in the latter case a waterproof being laid on the lap, on which the pad rests. The latter arrangement, similar to that described for epilation in the chapter on Dermatology, permits the patient to act as a secondary controller under orders, putting the hands down after the needle is inserted and removing them before the needle is removed, thus turning off and on smoothly the amount of current turned on and remaining on at the regular controller.

The active electrode is a fine sliver of zinc cut from a piece of 1/64 inch sheet zinc with long-handled surgical scissors or tinner's shears, attached to a sufficient length of No. 32 copper wire by winding a bared end of the wire about its butt and covering the joint with fused sealing wax. The latter then makes a convenient handle. The zinc needle thus made should be only about 2½ inches long so as not to be top-heavy, and the tip filed to a very fine point.

If one wishes to drive in the mercury ion with the zinc ion the tip of the zinc needle is dipped into weak sulphuric acid (one part of acid to ten parts of water) and then into mercury, the acid being washed off in water before insertion. The mercury ion alone may be used, with less destructive effect, by making a

gold needle from a piece of gold wire of sufficient length and attached to the conducting wire in the same manner. Such a gold needle may be improvised from the temple pieces of an old pair of gold spectacles provided the material is 18 karat, as less pure gold loses its alloy too much in the process of ionization. The gold needle is amalgamated in the same way as the zinc, at times with a little more rubbing of the needle in moist cotton to ensure an even coat, or dipping in stronger acid if it is tarnished. It should be remembered that amalgamation always makes a metal fragile and easily broken.

With the conjunctiva cocainized and the current turned off at the controller, the lid is everted, the needle inserted into the infected gland or granulation, and a current of from ½ milliampere to 2 milliamperes turned on slowly and maintained until it is judged that the infected area is sterilized, when the current is turned off by directing the patient to remove the hands from the pad, the needle is inserted in another spot, and the action repeated until the patient's or operator's enthusiasm lags. How much irritation should be produced in a contiguous series of such glands must be determined by the operator, and since the sterilized pocket will not be capable of reinfection from nearby foci for a week or more, it might be well to follow the plan employed in epilation to avoid too much irritation by destroying the infection in every other gland at first. An appropriate eye-wash completes the treatment, which may be repeated in the same lid in two or three weeks.

This method is a variation in polarity and in the use of a germicidal ion from that of Dr. T. D. Myers[1] in the development of which he consulted me in the nineties. Dr. Myers unquestionably produced results with the cathodic needle and the same current strength advised above, the modus operandi being electrolysis and alkaline destruction of the germs, but the progress of electrotherapeutic interpretation since indicates that even less power would be more effective with more definite germicidal ions. Besides, the anode always produces less pain than the cathode.

Ulcers of Cornea.—The iodin ion is recommended, applied by a wisp of cotton saturated with Lugol's solution on a blunt probe as cathode, with a current power of one half to two milliamperes.

[1] *Ophthalmic Review,* London, July, 1897.

Tuberculosis.—The technic advised for trachoma may be used, or the X-ray.

DIATHERMIC STIMULATION

The form of diathermic stimulation referred to is the use of the vacuum tube or non-vacuum tube current from the Tesla or Oudin circuits, applied either directly to the conjunctiva in affections of the conjunctiva or cornea in which active hyperemia is indicated as a local effect of mild degree, or placed on the closed lids for deeper or more diffused conditions. It is probable that there is a considerable variety of conditions in which these methods would be of value, which a study of the high frequency current (Chapter VIII) will suggest to the ophthalmologist, such as the cure of blepharitis marginalis (L. Webster Fox), etc.

SCLEROLYSIS

The principles of sclerolysis, or the electrolytic resolution of sclerosed and cicatricial tissue by a cathodic stream of ions containing the chlorin ion, are given at page 52. The experience of Leduc with this modality, applied by a cathode covered with absorbent cotton saturated with a weak solution of chlorid of sodium and placed on the closed lid in *scleritis* and *episcleritis* is there narrated.

From the repeated references to the treatment of *corneal opacities* by the cathode of the direct current in the writings of Alleman and others it would seem that even better results would be obtained by using the chlorin ion in the direct application to the opacity. Alleman[1] has this to say on the subject:

"I have treated a very considerable number of these cases, and have been more and more impressed with the value of the galvanic current, and Adler has lately reported very happy results from a similar method of treatment. The whole secret of success is in producing sufficient stimulation of the scar to bring about its gradual absorption and the deposit of clear corneal tissue, and in stopping just short of an irritation which shall produce active inflammatory conditions with stasis and a destruction of tissue. The duration of the opacity seems to have little to do with the prognosis, save that too recent cases do not progress as favorably, being more prone to severe inflammatory reaction. The improvement will, of course, depend largely on

[1] *Loc. cit.*, p. G. 11.

the nature of the case. Dense white scars yield very slowly to treatment while superficial opacities disappear with wonderful rapidity. In the cases of adherent leucomata with dense scars the center of the scar will require a longer time for its absorption, and it may not be advisable to continue treatment till all opacity disappears; but in patients who have persevered I have obtained very good results in clearing, and no unpleasant irritation was occasioned by the incarcerated iris.

"The clearing always begins at the margin of the scar, and consequently, when the scar is eccentric to the pupil and vision obscured by the edge of the opacity, visual improvement is very marked from the first. When the center of the scar is directly over the pupil, little visual improvement will be obtained until late in the treatment. During the application of the current the conjunctiva becomes injected and fine vessels are often seen running on to the clouded area. They disappear soon after the application, and their presence is a very encouraging sign of progress. At each sitting the eye flushes a little more easily, and the progress of the clearing can be readily followed by noting the diminishing area of the unvascularized scar. The results obtained have been most encouraging.

"I have endeavored to test thoroughly the advantages of the method, and have tried, as far as possible, to avoid such errors as might arise from careless observation, by using an artificial illumination of uniform brilliancy for the visual tests, an inelastic measure in testing vision at less than twenty feet, using different test letters at different sittings, and occasionally returning to the original card. I have stopped treatment for a time, and found the condition of the scar and vision to remain unchanged and the improvement to begin again immediately upon renewal of the treatment.

"From the observation of a number of cases extending over some considerable time, I am convinced that the use of electricity promises the most efficient and, in many cases, the only treatment of avail in opacities of the cornea of long standing.

"In making the application the operator stands behind the patient, whose head is thrown back in a reclining chair . . . (the other pole is directed to be pressed against the cheek by the patient, but a better plan is to have a pad in the lap on which contact is made by the patient's hands as directed after the active electrode is in place). . . . The controller is intrusted to an assistant who watches the needle of the meter as he turns the current on slowly after the active electrode is in contact. . . . With the thumb and the first finger of the left hand the lids are separated, after due cocainization, sufficiently far apart to prevent their coming into contact with the electrode, since

a current easily tolerated by the cornea is painful and irritating when passing through the margin of the lids. The electrode is held by the right hand, gently, in contact with the cornea, and careful watch is kept during the application that the contact is not broken nor too firm a pressure made against the cornea. The cathode is applied to the cornea, being theoretically indicated for the stimulation we wish to produce. The strength of current that may be safely employed varies widely in different cases. I begin treatment with ½ to 1 milliampere for one minute; should this be easily borne, I gradually increase the time up to three or four minutes, which is about as long as it is possible to hold the electrode in contact with the cornea without fatigue. The strength of current may be slightly increased at each application, until the patient's point of tolerance is reached. I place, as a limit in any case, a current followed by a slight irritation, which shall subside before the next application, which I usually make after an interval of one day. The strongest current that I have employed is 4 milliamperes for three minutes; but I do not think any better results were obtained by this than by a smaller current at more frequent intervals."

To convert this technic into that of sclerolysis, as advocated by Leduc, one has but to use a 1 per cent. solution of sodium chlorid on the active electrode. With the addition, it is likely that less current would be equally effective.

DILATATION OF STRICTURES OF THE LACRYMAL DUCT

The assistance that may be gained in the process of dilatation of the tear duct for stricture by making the probe the cathode of a weak direct current falls naturally under the heading of sclerolysis, even though a very weak current is employed to assist in the insertion of the probe and no destructive current is used. The remarks on the value of cathodic electrolysis in strictures of the urethra at page 340 apply equally well to strictures in this canal.

The ordinary lacrymal duct probe is best made the electrode for this purpose by covering all but the tip with a thin covering of fused shellac or sealing wax (page 290) and attaching a light wire to it for conduction as described in the preparation of the needle for trachoma. As the active surface is thus contracted to the small effective tip not more than ½ to 1 milliampere should be used.

DESTRUCTION OF TUMORS

Destructive electrocoagulation and ionization methods for epithelioma, carcinoma and sarcoma of this region are considered in Chapter XII; and of angiomas in Chapter XVI. These methods have an added advantage in this situation as they are often conservative of tissue and produce results with a minimum of cosmetic disfigurement.

Pterygium.—This wing-like growth on the conjunctiva has been reported cured by the cathodic needle, but a better and less tedious method is now available in electrodesiccation (page 267), a suitable electrode being applied directly to the tumor under cocain and an Oudin current so applied that the superficial tumor is whitened for the requisite depth only.

Tarsal Cysts.—Cathodic puncture with 1 to 2 milliamperes or desiccation will eradicate these cysts permanently in one application, without producing a depression in the lid.

Trichiasis.—Electric epilation was originally devised for the removal of errant eyelashes. For the technic see page 356.

MEDICAL USES OF ELECTRICITY IN OPHTHALMOLOGY

The authors referred to in the preceding paragraphs have much to say of the value of electricity in various diseases of the lens, retina, optic nerve and other portions of the inner parts of the eye. My own slight experience in some of these conditions is incomplete and inconclusive, much of it being based on the older modalities alone.

But ophthalmologists interested in the medicinal uses of physical therapy in eye affections should not fail to consult a recent article on this subject by Samuel J. Harris, of Boston, Mass.[1]

An interesting portion of Dr. Harris' paper is the report of his results in the avoidance, by physical therapy, of the too early resort to corrective lenses in moderate deficiencies in vision in both the young and in older patients. His conclusions on this subject are as follows:

"My conclusions are—that the persistent elongation of the zonule is so much easier to obtain, the younger the subject, and the less the accommodation has been exercised (amblyopic eye).

"That by massage hypermetropia may be considerably diminished: The younger the subject the better the results.

[1] American Journal of Electrotherapeutics and Radiology, Aug. 1923, page 254.

"That visual acuity is sometimes so much improved that an eye almost useless from amblyopia ex-anopsia as the result of high hypermetropia, may become serviceable for work.

"That some squinting eyes may thus recover sight enough for strabismus to be cured with the recovery of binocular vision.

"That different accommodative asthenopias are also susceptible to great improvement, and many cured.

"That some presbyopes may postpone the wearing of glasses.

"That some myopes gain notably in distant vision as well as in vision nearby without the short-sight diminishing in any way —that is, the acuteness of vision only improves.

"That in progressive myopia in young subjects whose defects yearly augment 3-5D., we can arrest the increase.

"That astigmatism is amenable to treatment by massage once the proper apparatus is perfected."

The question of the true value of medicinal applications of these physical forces in obscure intraocular conditions such as cataract and glaucoma can only be determined when trained ophthalmologists approach the subject with technical knowledge as well as an unbiassed mind.

For instance, it has been recently ascertained experimentally that a cataractous lens contains an excess of calcium and potassium. When the cathode of a direct current is passed through the closed lids and the orbit it is an established fact that these alkaline ions pass towards it from the deeper tissues, appearing nascent in the electrode covering. It is possible that an accumulation of calcium and potassium may in this way be withdrawn from the lens outwardly, towards the electrode.

It is hoped that a perusal of the rudiments of electrical technology as presented in the early chapters of this work will be of assistance in obtaining the proper technic. In any case the physician proposing to use electricity in eye affections is urged to read the chapters mentioned first.

Relief of Chronic Inflammatory Conditions of the Orbit.—It is likely that some of the reports in the older literature of relief of chronic inflammatory conditions of the eye by the direct and faradic currents would have been even more favorable if diathermy by the vacuum tube current had been available then. This method of inducing hyperemia in underlying structures is readily applied to the deeper parts of the eye by resting a curved tube on the *closed lid.* Electrodes for simultaneous application to both eyes have been constructed. (Fig. 156.) The handles of such electrodes for diathermy in the orbit should be long enough for the patient to hold them in apposition with the lid without fatigue by resting the elbow on a pillow in the lap. The Oudin current from the static, or the Oudin Tesla circuit of the transformer may be used, the former having a distinct polarity (the tube being properly attached to the cathode). As stated elsewhere (Chapter IX), this current, particularly with cathodic polarity, may have other effects than hyperemia. The applications should produce a comfortable heat, and have a duration of fifteen minutes to a half hour.

Vascular and Tissue Stimulation.—In addition to hyperemia from diathermy, tissue changes in such structures as the lens, retina and other deeper portions of the eye may be quickened

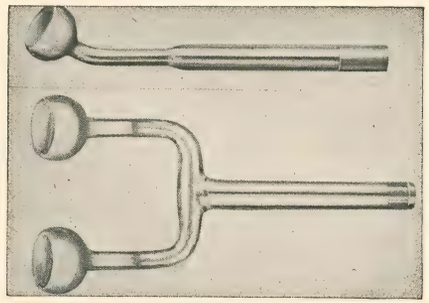


FIG. 156.—Vacuum Tube Single and Double Eye Electrodes.

by cathodic applications of the direct current, applied by a single or double eye-cup electrode (Fig. 157) in which warm normal salt solution or an ion solution is held by absorbent cotton. Such an electrode permits of currents up to 5 milliamperes or more to be sent into the eye or eyes through the closed lids, and may be used for either anions or cations, and for wave currents.

Coleman speaks favorably of rhythmic nongalvanic currents in such applications. As these carry more volume than the faradic current a slight flash may be observed when the current is strong enough, giving another rational modality of a stimulating character for the careful experimenter.

Muscle Stimulation.—For the stimulation of ocular muscles in which Wallerian degeneration (page 165) is present or suspected the nongalvanic rhythmic current may be employed in

preference to the galvanic sinusoidal, as the latter, when strong would stimulate the retina and organs of equilibration in the ear by diffusion. The dispersing pad should be on a distant part of the body and the active pad over the muscle, and a gentle current employed with rhythmic variation.

Cataract.—In incipient cases unaccompanied by diabetes or nephritis, Harris advises pneumo-massage three minutes, vacuum tube thermopenetration seven to ten minutes, followed by the cathode of the direct current, three to ten milliamperes for ten to fifteen minutes to closed lids. Once a week the last mentioned application is changed to the galvanic sinusoidal waves. The treatment will require from three months to two years.

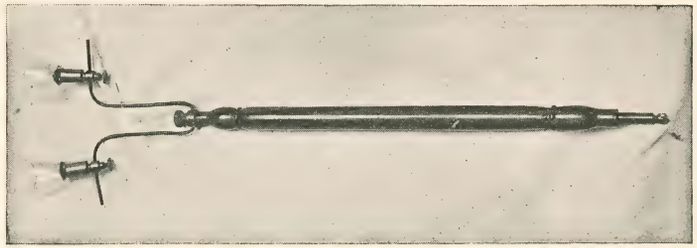


FIG. 157.—Double Eye Cup Electrode for Direct and Wave Currents. The cups are adjustable to the varying distance between the eyes of patients, and have the long handle suggested by Dr. A. B. Hirsh, with the connection point at the bottom. In one devised by Dr. Harris the connection to conductor is placed above the hand hold.

Conjunctivitis.—Vacuum tube thermopenetration to closed lids. (Harris.)

Epiphora.—Vacuum tube thermopenetration over the canaliculus and inside the nasal cavity three to five minutes is extremely beneficial, often obviating the necessity for probing. (Harris.)

Iritis.—During the acute stage the anode of the direct current, three to five milliamperes for seven to ten minutes daily for two or three days, associated with other local and with general treatment. Pain is said to be relieved. (Harris.)

In old cases Harris advises the cathode of the direct current similarly applied, both on the closed lids.

Keratitis.—Harris advises vacuum tube thermopenetration seven to ten minutes, followed by the cathode of the direct current

ten minutes with moderate current, both through the closed lid; also vibration of the third, fourth and seventh cervical vertebrae.

Optic Atrophy.—With the causal condition recognized and treated, Harris reports good results in improved vision by the use of the high frequency and direct currents applied through the lids. The treatment will require six months.

Retinal Hemorrhage.—Harris reports restoration of sight after the use of the direct current in a traumatic case. The anode was applied three days to check hemorrhage, followed by the cathode.

Retinitis Pigmentosa.—Good results in two cases are reported by Harris from a combined treatment of the cathode of the direct current, one to three milliamperes, alternating with the galvanic sinusoidal wave, blue light, vibration of the cervical and dorsal vertebrae and palming. The treatment was prolonged to a year in one case.

CHAPTER XIX

ELECTRICITY IN DISEASES OF THE NERVOUS SYSTEM

Mode of Action—Neuralgia—Neuritis—Muscular Atrophy of Peripheral Origin—Paralysis—Poliomyelitis—Lead Paralysis—Musculospiral Paralysis—Torticollis—Insomnia—Hysteria—Neurasthenia.

The electric treatment of diseases of the nervous system was the first medical use of electric currents. Its use preceded a correct knowledge of these affections and was therefore before a correct diagnosis was possible. Moreover, but little was known of electricity itself in these early days. These early beginnings of electrotherapy have unfortunately been crystallized by neurologic writers in this crude state and without much critical sifting. The natural result has been a disbelief in its value among many modern neurologists except as a means of diagnosing Wallerian degeneration (page 165), and as a convenient means of disguising suggestive therapeutics.

The subject should be reëxamined by neurologists in the light of modern developments in both etiology and diagnosis, on the one hand, and of the transformation of electric power in the body into heat, chemical action and stimulation of function on the other. This study will remove electricity from consideration as a rational treatment for many affections, notably those due to syphilis of the nervous system (where, nevertheless, the X-ray is of value); those too deep seated for it to reach *the actual seat of disease* in effectual dose; and those in which the degenerative consequences, such as hemiplegia, are beyond repair.

Modern electrotherapy has demonstrated a remedial value chiefly by *direct action on the locus morbi* and is least effective when this is impossible. A less important, though valuable mode of action is by reaching a *locus morbi* through stimulation of its afferent neurons. A third mode of action, that remains as valuable now as in older times, is the screen for suggestion—

a mode of action that it shares with many other therapeutic agents when suggestion is effective.

Hysteria.—Hysteria is a mental disease, whether occurring in woman or man. My own view of neurasthenia, which is frequently confounded with hysteria, is that neurasthenia is essentially different from hysteria, being a product of disordered abdominal functions (endocrine functions?), yielding products in the circulation that act as toxins on the nervous system. It is impossible to give an outline of the differential diagnosis between the two in this place, important as it is, there being daily failures to relieve neurasthenia by placing patients suffering from it on the "rest cure." The field for the rest cure—a most active subjection of the patient to the will of the physician—is in hysteria, in which isolation, mental and bodily discipline and rhythmic currents are of great value, the isolation meaning *complete removal* from home and all relatives.

To place a patient really suffering from neurasthenia under this method of rest cure is harmful, particularly so far as the rest in bed and isolation are concerned, and such cases are always failures under the method.

Owing to the fact that many patients suffering from hysteria have analgesic areas of the skin surface, and that neurasthenics are always hyperesthetic, a few indirect sparks to the back is an excellent diagnostic test. The hysteric is liable to be tickled into a laugh by this stimulation. The neurasthenic promptly votes it horrible. I have frequently planned successful campaigns in the treatment of a case thus demonstrated by this test to be hysteria (the regular administration of the sparks becoming a portion of the treatment), and have been able to detect neurasthenics by it, who should never receive this treatment.

Other modalities or remedies should be associated with the sparks in the treatment of hysteria, but particularly mental discipline, and if possible, an aroused desire for and a proper indulgence in hard work adapted to the patient's abilities.

Insomnia.—Following efforts at removal of the cause, a tendency to insomnia is usefully combated by a half hour's treatment by the static bath, or a mild static brush effluve to the head or back. These applications are particularly valuable if there is lowered blood pressure, and are said to be less effective if the pressure be high. If the blood pressure be at all above normal autocondensation is most restful and valuable, inducing sleep.

Such treatments may be given at any time during the day, but are best immediately before bedtime.

Lead Paralysis.—The extensor muscles of the wrist and fingers seem most prone to exhibit paralysis from lead poisoning, resulting in wrist-drop. In diagnosing this condition it should be recalled that the same muscles are affected in musculospiral paralysis. The latter is, however, almost invariably unilateral, and may be presumed to be present in unilateral wrist-drop if a history of sudden access is elicited, preceded by sleep on a hard surface while intoxicated.

Galvanic sinusoidal waves are specially indicated in lead paralysis, together with proper eliminative treatment.

Muscular Atrophy of Peripheral Origin.—Artificially produced rhythmic contractions of an atrophied muscle are unquestionably a tonic to a muscle cut off from its physiologic source of stimulation, provided the muscle be not too greatly tired by the exercise. These atrophies are produced by Wallerian degeneration, the course of which is determined by the extent of the original neuronic trauma or inflammation, and it should not be expected that restoration of muscular tone will be possible after the most extensive injuries; yet in all stages the exercise is serviceable. Rhythmic wave currents may be surging alternating current or galvanic sinusoidal, with small currents and slow waves. The surging current is least painful.

Musculospiral Paralysis.—The clinic physician was frequently confronted with unilateral wrist-drop in pre-prohibition days, due to pressure on the musculospiral nerve while an intemperate person slept with his head resting on the arm, which in turn rested on a hard surface. The degree of pressure paralysis, the stage of R D and the quickness of recovery under electric stimulation were in proportion to the depth of intoxication, for pain produced by this posture in this semisensory nerve would cause a shifting of the patient's position and relief of pressure if he were not comatose.

Neuralgia.—Unless a neuralgia is due to a neuritis of a nerve trunk accessible to the current the use of electricity in any form seems to be useless. The older modalities having been uniformly ineffective in my experience, I have recently tried the effect of diathermy applied to the area to which the pain was referred, notably in some cases of neuralgia of the fifth nerve. The result at times has been an aggravation of the pain. In these cases the frequent shifting of the pain to different branches of the

nerve indicated that the site of disturbance was central and not in the external portions of the nerve, hence the remedy did not reach the site of the disease.

Electrotherapeutic literature contains occasional references to the successful treatment of trigeminal neuralgia by the use of the quinin ion, applied by means of a carefully conformed, moist cathode to the whole of the painful region; but these cases may have been due to neuritis of the nerve trunks reached by the quinin ions. When the *locus morbi* is deeper, notably within the Gasserian ganglion, a current capable of conveying the ion to this depth would have to be greatly prolonged.

Mills [1] speaks favorably of the relief afforded by weak faradic currents in the supraorbital neuralgia of migraine, and doubtless several modern modalities in small dose would be of service in temporary relief.

Neuralgia of an extremity due to the pressure of a malignant growth, whether accompanied by neuritis or not, is aggravated by any physical treatment applied to the area of referred pain, particularly if the blood vessels are also compressed. Counter-pressure by bandaging gives temporary relief.

Neurasthenia.—In the treatment of neurasthenia electricity has an even greater field, in spite of its great aid to suggestion in hysteria; for by it we may stimulate abdominal functions (stimulation of endocrine secretions?), and assist in the elimination of autotoxins. As the latter are associated particularly with motor and secretory disorders of the digestive tract, a reader of the preceding portions of this work, particularly Chapter XIV, will understand that this is best done, in the writer's opinion, by the use of powerful abdominodorsal galvanic sinusoidal waves, of 100 to 200 milliamperes, and of a frequency not more than 11 to 50 per minute, or the whole strength of the slow wave of the Morse surging generator.

As neurasthenia is never caused by absolute overwork, in spite of many incorrect views to the contrary, but only aggravated by *relative overwork in a disordered, poisoned organism,* absolute rest of either body or mind is not indicated, but such work and exercise in the open air should be advised as can be well borne at the moment, to be increased as the patient's condition improves.

[1] "The Nervous System and Its Diseases," by Charles K. Mills, J. B. Lippincott Co., Philadelphia, p. 880.

Neuritis, Peripheral.—This condition is peculiarly the field of physiotherapy, and these measures should replace all medication of an analgesic character so far as possible. It is assumed that appropriate detoxic medication will be vigorously applied when indicated.

The inflamed nerve trunks are usually most accessible to the direct application of heat, preferably diathermic, ionization, or the mechanical effects on protoplasm of static waves or static sparks according to the stage of the disease, and progressive improvement is the rule when the modality is properly selected and applied.

Acute Neuritis has not been helped by the galvanic current in my experience. When the sciatic nerve is affected by acute neuritis it is rarely possible to bring the patient to the static generator for the wave treatment, for rest in bed is usually imperative. Here thermotherapy from a 50 to 100 watt electric light bulb should be applied to the tender spot while the patient is in bed, one hour of treatment followed by one hour of rest during the waking day. This is easily accomplished by attaching the bulb to an extension cord inserted in a nearby electric light socket, and enclosing the bulb in a pasteboard box some six inches deep by cutting a hole in its end for the base of the lamp. By means of a piece of cord the lamp itself is then tied against the bottom of the box so that, when the box is inverted over the painful spot, the lamp itself will not be too close to the skin. Such a white pasteboard box reflector is superior to a specially made cone or parabolic reflectors of metal as the edges of the latter become too hot.

Subacute or Chronic Neuritis of some weeks or longer duration demands diathermy, with well moulded tinfoil electrodes of appropriate size, applied over whatever spot is tender to deep pressure. After twenty minutes the static wave current, preferably rhythmic, should be applied to the same spot for another twenty minutes, gradually lengthening the spark gap as toleration is induced.

In chronic neuritis of the large nerve trunks, such as sciatica, the choice of modalities points to diathermy, with long, closely moulded electrodes on opposite sides of the limb, the narrower electrode over the nerve. Twelve hundred to 2500 milliamperes should be applied for twenty minutes, followed by the indirect static sparks to the painful area. Another modality that at times is more effective in a chronic case is the galvanic current,

cathode over the nerve and anode on the opposite side. Large kaolin pads should be used and a current of 100 to 200 milliamperes for fifteen minutes. The salicylic ion may be driven in from this cathode (page 56).

Paralysis.—I have seen little or no result from electric treatment of paralyses resulting from lesions within the brain. This statement is made after years of work of this nature in a clinic for nervous diseases. This experience does not include recent lesions.

Peripheral Paralyses presenting some stage of Wallerian degeneration are, on the other hand, greatly helped by diathermy and rhythmic wave currents. The normal trophic influence is cut off from these muscles, and though the consequent degeneration cannot be arrested, much can be done by active hyperemia and artificial contractions to replace the trophic influence until the neuron regenerates, it this be possible.

Facial Paralysis.—Paralysis of the seventh nerve, supplying all the facial muscles except the masseter, is the common form of facial palsy, and is usually unilateral. In the early stage the face becomes expressionless on the affected side, the mouth being drawn *towards the sound side.* Later, contraction of the affected side results, particularly in untreated cases, and the mouth may be drawn slightly to the affected side. Should the upper branches of the nerve be affected the orbicular muscle of the eye will participate in the paralysis, and complete closure of the lids become impossible.

The usual cause of facial palsy is neuritis, from exposure of one side of the face to an unusual draft, together with an underlying tendency to rheumatism; or neuritis from disease within the petrous portion of the temporal bone. But, slight cerebral hemorrhages may first show themselves by a unilateral palsy of the seventh nerve also. Since peripheral palsies are invariably accompanied by Wallerian degeneration in some degree and this is never shown in the cerebral variety, the presence of D R (page 165), in the slightest degree—merely a lessened faradic response in the affected side compared with the other side of the face, indicates that the case is a *peripheral* neuritis, and that the more serious intracranial disorder is absent.

The treatment of peripheral facial paralysis is that of neuritis of the nerve and atrophy of the muscles, described above. Very mild rhythmic wave currents are indicated, for the fifth nerve of sensation is intact, with unpleasant reflex responses of the

special senses to the waves. A well moistened, absorbent cotton-covered electrode about 2 by 2 inches is preferable, as no attempt is to be made to pick out particular muscles. The indifferent pad may be on the back. This treatment should be preceded by vacuum tube thermopenetration or radiant light.

Peripheral paralyses of the *laryngeal, accessorius* and other motor nerves should receive similar treatment.

Poliomyelitis.—The mistaken dictum that infantile paralysis should not receive electric treatment before three months has elapsed after the seizure has been definitely discarded. As shown by Snow, painless static wave applications may be made over the spine as soon as the case is diagnosed, with radiant light and heat to the affected muscles.

Later, rhythmic waves should be applied to the affected muscles, preceded by radiant light or diathermy. The waves should be slow and weak, and the applications should not last longer than ten or twelve minutes for fear of tiring the weakened muscles. The treatment should be kept up for months.

Torticollis.—Diathermy, followed by the static wave current is most valuable in this spasmodic condition, the application being made to the affected structures.

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